ADVANCING DENGUE FEVER PREPAREDNESS IN AFRICA: CHALLENGES, RESILIENCE, AND CONTRIBUTIONS TO GLOBAL HEALTH

AVANÇOS PARA VIGILÂNCIA DA DENGUE NA ÁFRICA: DESAFIOS, RESILIÊNCIA E CONTRIBUIÇÕES PARA A SAÚDE GLOBAL

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Abstract

Dengue Fever remains a pressing public health concern in the Global South, including in Africa, where limited resources, inadequate surveillance, weak health systems, climate change, and urbanization exacerbate the threat. This review study focuses on strategies to strengthen preparedness, capacity building efforts on surveillance, vector control, health system strengthening, community engagement, and research. Investing in training programs, research initiatives, and regional collaboration is vital. Advocacy for increased political commitment and resource allocation is necessary to drive policy support. African nations are actively contributing to global Dengue control efforts, showcasing resilience amidst adversity. There are promising prospects for improvement. Enhanced surveillance, capacity building, community engagement, research, and regional collaboration are identified as crucial strategies. Strengthening surveillance systems can provide accurate data for targeted interventions, while investing in healthcare infrastructure and training can improve diagnosis and treatment capabilities. Community engagement and education efforts can promote preventive behaviours, and research initiatives drive progress in Dengue prevention and control. Additionally, regional collaboration fosters knowledge exchange and resource sharing. By addressing these challenges and capitalizing on emerging opportunities, Africa can further strengthen its contribution to global Dengue control efforts. Through sustained investment, collaboration, and innovation, Africa has the potential to mitigate Dengue's impact and inspire similar efforts worldwide. Advocacy for increased political

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commitment and resource allocation is essential to drive policy support. By prioritizing Dengue control and implementing sustainable interventions tailored to local contexts, Africa can enhance public health resilience and contribute significantly to the global fight against Dengue.

Keywords: Africa; Dengue; preparedness; challenges; resilience; global health.

Resumo

A Dengue continua a ser uma preocupação importante de saúde pública no Sul Global, incluindo na África, onde recursos limitados, vigilância inadequada, sistemas de saúde fracos, alterações climáticas e urbanização agravam a situação. A presente revisão visa contribuir em ações para reforçar o preparo para o enfrentamento da Dengue, os esforços de capacitação em vigilância, no controle de vetores, reforço do sistema de saúde, envolvimento comunitário e para pesquisas. Investir em programas de formação, iniciativas de investigação e colaboração regional são vitais. A defesa de um maior compromisso político e da alocação de recursos é necessária para impulsionar o apoio necessário. As nações africanas contribuem ativamente para os esforços globais de controle da Dengue, demonstrando resiliência em meio a adversidade. Existem perspectivas promissoras de melhoria. Reforços em vigilância e recursos, o envolvimento comunitário, a investigação científica e a colaboração regional são identificados como estratégias cruciais. O reforço dos sistemas de vigilância pode fornecer dados precisos para intervenções específicas, enquanto o investimento em infraestruturas e formação em cuidados de saúde pode melhorar as capacidades de diagnóstico e tratamento. O envolvimento comunitário e os esforços educativos podem promover comportamentos preventivos, e as iniciativas de investigação impulsionam o progresso na prevenção e controle da Dengue. Além disso, a colaboração regional promove o intercâmbio de conhecimentos e a partilha de recursos. Ao enfrentar estes desafios e capitalizar as oportunidades emergentes, a África pode reforçar ainda mais a sua contribuição para os esforços globais de controle da Dengue.
Palavras-chave: África; Dengue; preparo; desafios; resiliência; saúde global.

Introduction

Dengue fever, a viral infection transmitted by mosquitoes, poses a significant global public health concern, particularly in tropical and subtropical regions[1,2]. The disease has rapidly spread across all World Health Organization (WHO) regions in recent years, with Africa experiencing a surge in cases. According to the WHO, Africa accounted for approximately 0.5% of the global dengue burden in 2010[3,4], but this proportion has been gradually increasing. The disease is now endemic or sporadically epidemic in several African countries, particularly in coastal regions and urban centres. Countries in East Africa, including Tanzania, Kenya, and Mozambique, as well as those in West Africa, such as Senegal and Nigeria, have reported dengue outbreaks in recent years. Additionally, cases have been documented in countries with temperate climates[5-7].

The Dengue virus is primarily transmitted by female Aedes mosquitoes, notably *Aedes aegypti* and *Ae. albopictus*, which also transmit other diseases such as chikungunya, yellow fever, and Zika. Dengue's prevalence in tropical regions varies based on factors such as rainfall, temperature, and urbanization patterns. Dengue's transition from monkeys to humans occurred approximately 800 years ago, and human carriers are the primary source of the virus, sustaining the urban transmission cycle by infecting uninfected Aedes aegypti mosquitoes[1, 8].

Dengue fever manifests as a severe flu-like illness characterized by high fever and additional symptoms such as headache, muscle and joint pain, nausea, and rash. Although seldom fatal, severe complications, known as Dengue haemorrhagic fever (DHF) or severe Dengue, can lead to hospitalization and death, particularly among children in Asia and Latin America[4,5]. While there is no specific treatment for Dengue, early detection and proper medical care can significantly reduce mortality rates. Lifelong immunity against a specific serotype develops following infection, but subsequent infections with other serotypes increase the risk of severe Dengue. Vector control remains the primary method of Dengue prevention[3,6], though a Dengue vaccine is licensed for use in endemic areas[2]. Despite historically low risk, recent outbreaks and environmental changes underscore the importance of addressing Dengue in Africa[5,6].

Enhancing Dengue preparedness on the continent is crucial to safeguard public health and socioeconomic development. This article delves into Africa's unique challenges in Dengue preparedness, the resilience required to overcome these obstacles, and the continent's pivotal role in boosting global health security amidst the Dengue fever threat.

The virology of Dengue Fever

Dengue fever is caused by the Dengue virus – DENV, a member of the Flaviviridae family[1,8]. The mature Dengue virus possesses envelope proteins (E) that are crucial for viral attachment and entry into host cells. These envelope

proteins form protruding spikes on the surface of the virus particle. The membrane protein (M) is embedded within the lipid bilayer of the viral envelope, providing structural support to the virus particle. Surrounding the nucleocapsid, the mature Dengue virus is enveloped by a lipid membrane derived from the host cell's plasma membrane during the viral budding process. Within the lipid envelope lies the capsid (C), which encapsulates the viral genome and essential proteins, maintaining the integrity of the viral RNA[a]. The Dengue virus genome consists of a single-stranded, positive-sense RNA molecule (Viral (+) ssRNA). This RNA serves as the genetic blueprint for viral replication and protein synthesis within host cells. The 3' untranslated region of the Dengue virus genome (3' Stem-loop - SL) contains a stem-loop structure essential for viral RNA replication and translation regulation. Another structural element present in the 5' untranslated region of the Dengue virus genome is the stem-loop A (SLA), which plays a role in viral replication and translation initiation.

The 5' end of the Dengue virus RNA genome is capped with a 7-methylguanosine (7MeG) cap structure, with a 2'-O-methylation modification. This cap structure facilitates viral mRNA stability and translation efficiency. In the immature form of the Dengue virus, the viral particles contain an additional structural protein known as prM (precursor membrane protein). This prM protein covers the E protein spikes on the surface of the virus, shielding them from premature fusion with host cell membranes during viral egress[8-10].

The life cycle of the Dengue virus begins when an infected mosquito, usually *Aedes aegypti* or *Aedes albopictus*, feeds on a human host. During the blood meal, the mosquito injects the virus into the human's bloodstream. Once inside the human host, the virus targets various cells, particularly those of the immune system and endothelial cells lining blood vessels. The intrinsic incubation period (the time from infection to the onset of symptoms) typically ranges from 4 to 10 days[b]. However, it can vary depending on factors such as the individual's immune response and the specific viral strain[1,8].

Meanwhile, in the mosquito, the virus undergoes extrinsic incubation, a process that takes about 8 to 12 days. During this period, the virus replicates within the mosquito's cells, eventually migrating to its salivary glands. Once the extrinsic incubation period is complete, the mosquito becomes infectious and can transmit the virus to other humans during subsequent blood meals. Mosquitoes remain infected for the duration of their lifespan, which can range from a few weeks to several months, depending on environmental conditions. Human infection with Dengue virus can manifest as a spectrum of clinical presentations, ranging from mild fever (dengue fever) to severe forms such as dengue

[a] *Note*. The morphology of Dengue virus can be found elsewhere (i.e., GeneTex)[10].

[b] *Note*. Readers interested in further details regarding urban dengue virus cycle in humans and mosquitoes might benefit from consulting external sources, such as Guzmán *et al.*[8].

haemorrhagic fever (DHF) and dengue shock syndrome (DSS). Symptoms may include high fever, severe headache, joint and muscle pain, nausea, vomiting, rash, and in severe cases, bleeding and organ failure[8,9].

There are four distinct serotypes of the Dengue virus: DENV-1, DENV-2, DENV-3, and DENV-4[1,10]. The circulation of multiple Dengue virus serotypes contributes to the complexity of Dengue epidemiology. In regions where Dengue is endemic, individuals may be exposed to multiple serotypes over their lifetime, leading to the potential for sequential or simultaneous infections with different serotypes. This phenomenon is known as sequential or secondary Dengue infection and can increase the risk of severe Dengue, such as Dengue haemorrhagic fever (DHF) or Dengue shock syndrome (DSS). Each Dengue virus serotype can cause a spectrum of clinical manifestations ranging from asymptomatic infection to severe and potentially life-threatening disease. While infection with one serotype typically confers lifelong immunity against that specific serotype, subsequent infections with a different serotype can increase the risk of severe Dengue due to antibody-dependent enhancement (ADE). ADE occurs when non-neutralizing antibodies from a previous infection bind to a different Dengue virus serotype, facilitating viral entry into host cells and exacerbating the immune response. The presence of multiple Dengue virus serotypes poses challenges for vaccine development. A successful Dengue vaccine must provide protection against all four serotypes to be effective in endemic regions. Several Dengue vaccine candidates targeting multiple serotypes have been developed and evaluated in clinical trials. These vaccines aim to induce a balanced and protective immune response against each serotype without causing ADE.

Monoclonal antibodies[c] targeting conserved epitopes on the envelope protein of all four Dengue virus serotypes (DENV1-4), known as DENV broad-neutralizing antibodies (DENV bNAbs), represent a promising approach for Dengue virus prevention and treatment[11].

These DENV bNAbs typically target highly conserved regions within the envelope protein, such as the fusion loop or the A-strand epitope, which are essential for viral entry and fusion with host cells. By binding to these conserved epitopes, the monoclonal antibodies can effectively neutralize all four serotypes of the Dengue virus. One example of a DENV bNAb is 4E11, which targets a fusion loop epitope conserved across all four Dengue virus serotypes. 4E11 has demonstrated potent neutralizing activity against DENV1-4 in vitro and in animal models, making it a promising candidate for further development as a therapeutic agent. Other DENV bNAbs, such as DENV-2D22 and DENV-1C19, target similar conserved epitopes on the envelope protein and have shown broad-spectrum

[c] *Note*. A useful resource on monoclonal antibodies that can neutralize Dengue serotypes is provided elsewhere[11].

neutralizing activity against multiple Dengue virus serotypes.

These monoclonal antibodies hold significant potential for the prevention and treatment of Dengue fever and its associated complications. They may be used prophylactically to prevent infection in individuals at risk of Dengue virus exposure or therapeutically to reduce disease severity and improve clinical outcomes in patients with active Dengue virus infection. Continued research and development efforts aimed at optimizing the efficacy, safety, and scalability of these DENV bNAbs are essential for their successful translation into clinical use and their potential to address the global burden of Dengue fever[1,8,11].

Global Burden of Dengue Fever

Since the 1960's, the global burden of Dengue fever has surged, presenting a significant worldwide health concern. Presently, approximately half of the global population across 128 countries is vulnerable to the disease[4]. Despite its widespread impact, the true extent of Dengue cases remains obscured, with many instances being underreported or misclassified. Recent estimates suggest a staggering annual incidence of 390 million Dengue infections, with around 96 million cases displaying clinical manifestations[12].

Member States within three WHO regions consistently report Dengue cases annually. Reported cases have seen a notable uptick, escalating from 2.2 million in 2010 to 3.2 million in 2015. This increase can be partly attributed to enhanced surveillance efforts aimed at capturing all Dengue instances. Dengue's epidemiological patterns, characterized by the prevalence of multiple virus serotypes and its profound impact on human health and global economies, underscore the complexity of the disease. Initially confined to only nine countries before 1970, Dengue fever is now endemic in over 100 countries across Africa, the Americas, the Eastern Mediterranean, South-East Asia, and the Western Pacific regions, with the Americas, South-East Asia, and the Western Pacific being particularly affected[3,4,7].

Over the past two decades, there has been a significant rise in the global occurrence of dengue fever, presenting a considerable public health challenge. Between 2000 and 2019, reported cases worldwide surged tenfold, escalating from 500,000 to 5.2 million cases, reaching an unprecedented peak in 2019 across 129 countries[7].

Following a temporary decline in cases during the years 2020-2022 due to the COVID-19 pandemic and reduced reporting rates, resurgence in dengue cases has been observed globally in 2023. This resurgence is marked by a notable increase in the number, scale, and simultaneous outbreaks in regions previously unaffected by dengue. Since the onset of 2023, ongoing transmission coupled with an unexpected surge in cases has resulted in close to a historic high, with over five million reported cases and more than 5000 dengue-related deaths in over 80 countries/territories across five WHO regions globally.

Approximately 80% of these cases, amounting to 4.1 million, have been reported in the Region of the Americas, making dengue the most prevalent arbovirus in the region, with cyclic epidemics occurring every 3 to 5 years. Additionally, clusters of locally acquired dengue cases have been reported in the WHO European Region. However, these figures likely underestimate the true burden of the disease due to the asymptomatic nature of many primary infections and the lack of mandatory dengue reporting in numerous countries[7].

African Burden of Dengue Fever

Historically, Africa has been considered less affected compared to other regions like Asia and Latin America, recent studies and reports suggest an emerging threat. Currently, Africa ranks among the top four regions most affected by arboviral diseases, including dengue, yellow fever, chikungunya, O'nyong nyong, Rift Valley fever, and Zika. The prevalence of dengue fever has been steadily increasing across the continent in recent years. Although data on dengue fever prevalence in Africa can be limited and variable due to underreporting, surveillance gaps, and differing diagnostic capacities among countries, there is growing evidence of its emergence and spread[3].

Dengue fever incidence in Africa has been rising, with an increasing number of reported cases and outbreaks in several countries. According to the World Health Organization (WHO), Africa accounted for approximately 0.5% of the global dengue burden in 2010[3], but this proportion has been gradually increasing. The disease is now endemic or sporadically epidemic in several African countries, particularly in coastal regions and urban centres. Countries in East Africa, including Tanzania, Kenya, and Mozambique, as well as those in West Africa, such as Senegal and Nigeria, have reported dengue outbreaks in recent years. Additionally, cases have been documented in countries with temperate climates[13-20].

In 2023, the African region reported 171,991 dengue cases and 753 deaths. Evidence of dengue circulation has been detected in local populations and among travellers returning from over 30 African countries. Outbreaks have been reported in 15 of the 47 countries, with Burkina Faso experiencing a significant increase in dengue cases compared to previous years. As of December 19, 2023, outbreaks are ongoing in 11 countries and have been declared over in Chad, Guinea, Mauritius, and São Tomé and Príncipe[7,20].

Dengue transmission follows a cyclic pattern, with large outbreaks occurring every 3-4 years. During the COVID-19 pandemic, there was moderate transmission in some regions and low transmission in others, leading to a buildup of individuals without immunity to certain dengue virus strains. However, data on circulating dengue serotypes remains limited[5,6]. The burden of dengue in Africa is not well understood due to similarities in symptoms with other tropical febrile illnesses, limited laboratory capacity for timely detection

and confirmation, and inadequate surveillance and reporting systems. Furthermore, Dengue fever in Africa exhibits diverse epidemiological patterns, ranging from sporadic cases to large-scale outbreaks. Urban areas with high population densities and inadequate sanitation infrastructure are particularly susceptible to dengue transmission[13,14]. Furthermore, seasonal variations in rainfall and temperature influence the timing and intensity of outbreaks in different regions. Underreporting of dengue fever cases remains a significant challenge in many African countries due to limited diagnostic capacity, misdiagnosis, and lack of awareness among healthcare providers. Surveillance systems for dengue fever are often weak or fragmented, hindering accurate assessment of disease burden and trends. No doubt, Dengue fever poses a substantial public health burden in Africa, leading to morbidity, mortality, and economic losses. Severe cases of dengue haemorrhagic fever and dengue shock syndrome can overwhelm healthcare systems, particularly in resource-limited settings where access to medical care is constrained[7,16,20-22].

Risk and epidemiological drivers of Dengue Fever in Africa

Many African countries exhibit sporadic or uncertain Dengue transmission, characterized by occasional outbreaks or unclear surveillance data[7,16]. However, several nations, particularly those in East Africa and parts of West Africa, experience frequent or continuous Dengue transmission. African countries, such as Burkina Faso, Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan, and the United Republic of Tanzania are more prone to sustained outbreaks and may have a higher burden of Dengue cases. These regions are marked by conducive environmental conditions for the Aedes mosquito vector and dense human populations, fostering sustained transmission cycles. Countries like Algeria, Botswana, Libya, Morocco, South Africa and Tunisia have no evidence of risk [20-22] (Table 1).

The epidemiology of dengue fever in African countries is undergoing significant changes, influenced by various factors including climate change, urbanization, population movement, and globalization[23-26]. Understanding these changes is crucial for effective disease prevention and control strategies.

i. Climate Change

The impacts of climate change are expected to exacerbate the spread of dengue fever in Africa. Rising temperatures and changing rainfall patterns create favourable conditions for mosquito breeding.

Climate change plays a significant role in altering the distribution and abundance of Aedes mosquitoes, the primary vectors of dengue virus. Rising temperatures and changing rainfall patterns create favourable conditions for mosquito breeding and survival, extending the geographic range of dengue transmission in Africa. Additionally, extreme weather events

such as floods and droughts can exacerbate mosquito breeding and dengue outbreaks[28-30].

ii. Urbanization

Rapid urbanization is a major driver of dengue transmission in Africa. The proliferation of informal settlements with inadequate housing, water, and sanitation infrastructure creates conducive environments for Aedes mosquito breeding. Urbanization also facilitates human-mosquito contact, increasing the risk of dengue transmission in densely populated areas[31].

iii. Population Movement and Globalization

Increased travel and trade contribute to the globalization of dengue fever. Infected individuals traveling from endemic regions can introduce the virus to new areas, leading to localized outbreaks or sustained transmission. Population movement within Africa, as well as international travel and trade, facilitate the spread of dengue viruses between countries and continents[31-33].

iv. Geographical Spread

Dengue fever was historically considered rare in Africa, with most cases reported in Asia and Latin America. However, over the past few decades, the disease has been spreading across the African continent. Initially concentrated in coastal areas, dengue is now increasingly reported in urban and peri-urban areas across Africa[31-33].

Table 1. Dengue risk status across different African countries and regions

Country	Region	Risk Status
Angola	Central Africa	Sporadic/Uncertain
Benin	West Africa	Sporadic/Uncertain
Burkina Faso	West Africa	Frequent/Continuous
Burundi	East Africa	Sporadic/Uncertain
Cameroon	Central Africa	Sporadic/Uncertain
Cape Verde	West Africa	Sporadic/Uncertain
Central African Republic	Central Africa	Sporadic/Uncertain
Chad	Central Africa	Sporadic/Uncertain
Congo	Central Africa	Sporadic/Uncertain
Congo (Democratic Republic of)	Central Africa	Sporadic/Uncertain
Cote d'Ivoire	West Africa	Sporadic/Uncertain
Djibouti	East Africa	Frequent/Continuous
Egypt	North Africa	Sporadic/Uncertain
Equatorial Guinea	Central Africa	Sporadic/Uncertain
Eritrea	East Africa	Frequent/Continuous
Ethiopia	East Africa	Frequent/Continuous
Gabon	Central Africa	Sporadic/Uncertain
Gambia	West Africa	Sporadic/Uncertain
Ghana	West Africa	Sporadic/Uncertain
Guinea	West Africa	Sporadic/Uncertain
Guinea-Bissau	West Africa	Sporadic/Uncertain
Kenya	East Africa	Frequent/Continuous
Liberia	West Africa	Sporadic/Uncertain
Madagascar	East Africa	Sporadic/Uncertain
Malawi	East Africa	Sporadic/Uncertain
Mali	West Africa	Sporadic/Uncertain
Mauritius	East Africa	Sporadic/Uncertain
Mozambique	East Africa	Sporadic/Uncertain
Namibia	Southern Africa	Sporadic/Uncertain
Niger	West Africa	Sporadic/Uncertain
Nigeria	West Africa	Sporadic/Uncertain
Reunion	East Africa	Sporadic/Uncertain
Rwanda	East Africa	Sporadic/Uncertain
Sao Tome and Principe	West Africa	Sporadic/Uncertain
Senegal	West Africa	Sporadic/Uncertain
Sierra Leone	West Africa	Sporadic/Uncertain
Somalia	East Africa	Frequent/Continuous
South Sudan	East Africa	Sporadic/Uncertain
Sudan	East Africa	Frequent/Continuous
Togo	West Africa	Sporadic/Uncertain
Uganda	East Africa	Sporadic/Uncertain
United Republic of Tanzania	East Africa	Frequent/Continuous
Zambia	Southern Africa	Sporadic/Uncertain
Zimbabwe	Southern Africa	Sporadic/Uncertain

Source: Adapted from the CDC[20].

v. Socioeconomic Factors

Socioeconomic factors such as poverty, inadequate healthcare infrastructure, and limited access to preventive measures also influence the epidemiology of dengue fever in African countries. Vulnerable populations living in marginalized urban areas are disproportionately affected by dengue, as they may lack access to healthcare services and mosquito control interventions[34-38].

Changing Dengue Virus Dynamics

One of the key drivers influencing dengue dynamics in Africa is the introduction of new virus serotypes and genetic variants [39,40]. The presence of multiple dengue virus serotypes (DENV-1 to DENV-4) poses a unique challenge, as infection with one serotype does not confer immunity against the others. Consequently, immune-naive populations may experience severe forms of dengue upon exposure to a new serotype, leading to heightened morbidity and mortality rates. Furthermore, the emergence of genetic variants within these serotypes adds another layer of complexity to disease transmission dynamics. Genetic mutations can impact various aspects of the virus, including virulence, transmissibility, and susceptibility to antiviral interventions. Therefore, surveillance efforts must be bolstered to monitor the emergence and spread of novel genetic variants, enabling prompt response and adaptation of control strategies. The introduction of novel serotypes and genetic variants into African populations can significantly alter disease transmission dynamics and clinical outcomes. Immune-naive populations may be more susceptible to severe forms of dengue (such as dengue haemorrhagic fever and dengue shock syndrome) leading to increased morbidity and mortality. Moreover, healthcare systems in many African countries may be ill-equipped to handle the surge in dengue cases, exacerbating the burden on already strained resources[41-43].

Changing Dengue Virus Dynamics Challenges Facing Africa in combating Dengue fever

Africa's battle against Dengue is fraught with multifaceted challenges (Figure 1). Weak surveillance systems, limited healthcare resources, and inadequate infrastructure exacerbate the threat posed by this mosquito-borne illness.

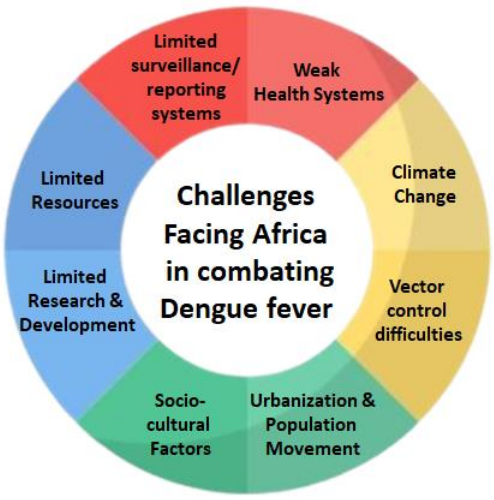

Figure 1: A summary of Challenges facing Africa in combating Dengue fever.

Moreover, the continent's diverse ecological landscapes and socio-economic disparities further complicate control efforts[2,44]. Details about each of these challenges are provided next.

i. Limited resources

Many African countries struggle with limited financial and infrastructural resources, hindering their ability to implement comprehensive Dengue prevention and control measures[2,45].

ii. Limited surveillance and reporting systems

Inadequate surveillance systems hinder accurate disease mapping and monitoring, leading to underestimation of the disease burden[2,45].

iii. Weak health systems

Many African countries have limited healthcare resources and infrastructure, making early diagnosis and proper management of dengue cases challenging. Weak health systems in some regions impede surveillance, diagnosis, and treatment efforts, leading to underreporting and inadequate management of Dengue cases[2,44].

iv. Climate change

The changing climate exacerbates vector breeding and transmission patterns, increasing the geographical spread of Dengue fever in Africa and challenging existing control strategies[29,30].

v. Urbanization and population movement

Rapid urbanization and population movement facilitate the spread of Dengue virus by creating favourable environments for mosquito breeding and facilitating the movement of infected individuals across borders[2,20,31].

vi. Vector control difficulties

Aedes mosquitoes breed in various water containers commonly found in urban and peri-urban environments, posing challenges for effective vector control measures. Inadequate vector control measures and resistance to insecticides pose significant challenges to Dengue prevention efforts in Africa, particularly in regions where mosquitoes thrive[6,34,38].

vii. Socio-cultural factors

Socio-cultural beliefs and practices can influence community engagement with Dengue prevention and control efforts. Misconceptions about the causes and transmission of Dengue, as well as traditional healing practices, may result in reluctance to adopt recommended preventive measures or seek timely medical care. Addressing these socio-cultural factors requires tailored communication strategies and community involvement to build trust and promote behaviour change[46,47].

viii. Limited research and development

Africa faces challenges in research and development specific to Dengue fever. Limited funding and capacity for scientific research hinder the development of locally relevant diagnostic tools, vaccines, and therapeutics. Additionally, the lack of comprehensive epidemiological data on Dengue transmission dynamics in Africa impedes the design and evaluation of effective control strategies tailored to the continent's unique ecological and socio-economic context. Increasing investment in research and fostering collaborations between academia, public health institutions, and governments is crucial for advancing Dengue research and development in Africa[9,30,48].

ix. Vaccine challenge

Dengue vaccines represent a promising tool in the fight against this mosquito-borne disease[26]. Recent developments in dengue vaccine research have yielded several candidates, each with its unique strengths and challenges. One of the most significant breakthroughs is the development of the CYD-TDV vaccine, commercially known as Dengvaxia, which has been licensed in several countries.

However, Dengvaxia has faced challenges, particularly regarding its efficacy and safety profile, particularly in seronegative individuals. This has prompted the need for alternative vaccine candidates with improved efficacy and safety profiles, especially in regions where dengue is endemic. Several ongoing challenges hinder the development and deployment of dengue vaccines. These include the complexity of dengue virus serotypes and the risk of antibody-dependent enhancement (ADE), where prior infection with one serotype may worsen subsequent infections with different serotypes.

Current candidates in various stages of development include live attenuated vaccines, recombinant vaccines, and viral vector vaccines. Notable candidates include TAK-003 (also known as Takeda's TDV), a live attenuated vaccine showing promising results in phase 3 clinical trials, and TV003/TV005, a tetravalent live attenuated vaccine developed by the National Institutes of Health (NIH). Addressing ongoing challenges and advancing promising candidates will be crucial in developing effective dengue vaccines that can provide long-term protection against all four serotypes of the virus while ensuring safety and accessibility for populations at risk[49,50].

Africa resilience and contribution to global health in the fight against Dengue fever

African resilience in the fight against Dengue Fever is multifaceted, involving various strategies and efforts aimed at prevention, control, and mitigation of the disease's impact. Next, some key aspects of African resilience and contribution in combating Dengue fever are presented (Figure 2).

Figure 2: Africa Resilience and contribution to global health in the fight against Dengue fever: key aspects.

i. Strengthening health systems

A resilient healthcare system forms the backbone of Dengue preparedness. Strengthening primary healthcare facilities, equipping them with essential supplies and personnel, and integrating

Dengue management protocols into existing health frameworks are imperative steps towards bolstering readiness. Furthermore, fostering community engagement and education initiatives can empower individuals to take proactive measures against Dengue, thereby mitigating its impact. African countries are currently training and re-training their healthcare workers in Dengue diagnosis and treatment, stockpiling medical supplies, and improving access to healthcare services, especially in remote and underserved areas[5,22].

ii. Enhanced surveillance and reporting

Developing robust surveillance systems is crucial for early detection and response to Dengue outbreaks. Many African countries have enhanced their disease surveillance networks, enabling rapid identification of Dengue cases and implementation of targeted interventions to contain the spread.

Strengthening surveillance systems and improving reporting mechanisms can help accurately assess the burden of Dengue fever in Africa, enabling more targeted interventions and resource allocation. Enhance disease surveillance mechanisms is essential for improving early detection and response. Health agencies must implement robust reporting systems to accurately capture dengue cases and outbreaks[14,22,24].

iii. Capacity building

To enhance Dengue preparedness, concerted efforts must be made towards capacity building across multiple fronts. Firstly, robust surveillance mechanisms are indispensable for early detection and response to outbreaks. This necessitates investments in diagnostic tools, training of healthcare personnel, and the establishment of data-sharing networks.

Investing in healthcare infrastructure, training healthcare workers, and enhancing laboratory capacity are crucial for improving Dengue diagnosis, treatment, and research capabilities across the continent. Government at all levels must ensure

availability of diagnostic tools and medical supplies in healthcare facilities.

African countries are currently investing in building capacity for Dengue surveillance, diagnosis, and management within their healthcare systems. This includes training healthcare workers, establishing laboratory networks, and strengthening disease surveillance infrastructure. By enhancing local capacity, Africa contributes to global health security by improving the early detection and response to Dengue outbreaks, thereby reducing the risk of international spread[15,22,24].

iv. Implementing vector control measures

Additionally, prioritizing vector control strategies tailored to local contexts is essential for curbing mosquito populations and reducing transmission rates. It is important to conduct comprehensive vector surveys to identify breeding sites and assess mosquito population dynamics.

Vector management approaches, including larval source reduction, insecticide spraying, and community-based interventions are essential. Also, it is imperative to promote environmental sanitation and waste management practices to minimize mosquito breeding sites.

African countries employ vector control measures to reduce mosquito populations, including indoor residual spraying, use of larvicides, and distribution of insecticide-treated bed nets. Additionally, innovative approaches like Wolbachia-infected mosquito releases are being explored as a sustainable method of mosquito population control[6,34,38].

v. Community engagement and education

Communities play a vital role in Dengue prevention through activities such as environmental clean-up campaigns, proper waste disposal, and elimination of mosquito breeding sites. Community health workers and local leaders often lead awareness campaigns to educate people about Dengue symptoms, prevention measures, and the importance of seeking medical care.

African governments, non-governmental organizations, and community groups engage in advocacy and awareness-raising activities to promote Dengue prevention and control measures. Public health campaigns, educational initiatives, and community mobilization efforts aim to raise awareness about Dengue transmission, symptoms, and prevention strategies.

By empowering communities to take proactive measures against Dengue, Africa contributes to global efforts to reduce the burden of this disease. Empowering communities through education and awareness campaigns can promote preventive behaviours, such as eliminating mosquito breeding sites and seeking prompt medical care for Dengue symptoms. Raising public awareness about dengue symptoms, prevention, and

the importance of seeking timely medical care is very critical[24,46,47].

vi. Research and innovation

Advancement in Dengue research is pivotal for developing effective prevention and control strategies. Investing in research initiatives aimed at understanding the epidemiology, transmission dynamics, and genetic diversity of Dengue strains circulating in Africa is critical. Furthermore, leveraging technological innovations such as predictive modelling and novel vector control methods can revolutionize Dengue management on the continent. Supporting research initiatives focused on Dengue prevention, control, and vaccine development can drive innovation and foster partnerships between African institutions and global stakeholders.

The government and the people must be intentional in investing in research to understand the epidemiology, vector dynamics, and genetic diversity of dengue viruses in Africa. Public professionals must develop and evaluate new tools and strategies for dengue prevention, such as novel vector control methods and vaccines.

Foster partnerships between academia, government agencies, and the private sector to accelerate research and innovation in dengue control are very important. African researchers are actively involved in studying Dengue epidemiology, vector biology, and vaccine development.

Collaborative research initiatives with international partners contribute to the generation of evidence-based strategies for Dengue control tailored to the African context.

Studies on Dengue epidemiology, vector ecology, clinical management, and vaccine development are conducted in collaboration with international partners. These efforts contribute to the development of evidence-based strategies for Dengue prevention, control, and treatment that benefit not only Africa but also other Dengue-endemic regions worldwide[9,30,48].

vii. Fostering cross-sectoral and regional collaboration

Addressing Dengue requires collaboration across various sectors including health, environment, education, and urban planning to enhance data collection and analysis. Governments, non-governmental organizations, academic institutions, and international agencies collaborate to implement integrated approaches that tackle Dengue from multiple angles. Also, collaboration across borders is indispensable for combating Dengue in Africa.

Regional partnerships facilitate the exchange of best practices, resources, and expertise, thereby enhancing collective preparedness and response capabilities. Platforms for collaboration, such as the African Union and regional health organizations, play a pivotal role in coordinating efforts and mobilizing support. African countries collaborate

regionally and with international partners to address Dengue Fever through initiatives such as the African Union's Africa Centres for Disease Control and Prevention (Africa CDC). These collaborations facilitate information sharing, joint research projects, and coordinated response efforts to Dengue outbreaks and other public health emergencies.

By working together, African nations amplify their collective impact on Dengue control and contribute to global health security. Strengthening regional collaborations and sharing best practices among African countries can facilitate the exchange of knowledge, resources, and expertise in Dengue control efforts. It is important for the continent to establish regional networks for surveillance, outbreak response, and capacity-building initiatives and leverage on existing regional frameworks, such as the African Union and regional health organizations, to prioritize dengue fever on the public health agenda[22,23].

viii. Advocating for political commitment and resource allocation

Sustained political commitment and adequate resource allocation are fundamental for scaling up Dengue preparedness efforts in Africa. Advocacy initiatives aimed at garnering support from policymakers, donors, and international organizations are paramount. Emphasizing the interconnectedness of global health security and the need for a coordinated response to Dengue can catalyse action at the highest levels[22-24].

ix. Integrating climate change adaptation strategies

In response to the intricate interplay between climate dynamics and Dengue transmission, African nations are proactively integrating climate change adaptation strategies into their healthcare frameworks. Central to this adaptation effort is the reinforcement of early warning systems tailored to anticipate and respond to climate-induced disease outbreaks promptly[29]. These systems leverage meteorological data and epidemiological surveillance to forecast Dengue risk areas, allowing for timely deployment of preventive measures.

Moreover, African countries are prioritizing the implementation of climate-resilient vector control strategies to mitigate Dengue transmission amidst changing environmental conditions. These measures encompass innovative approaches such as biological control methods, habitat modification initiatives, and community-based vector management programs.

By fostering the resilience of vector control interventions to climatic variability, these nations aim to sustainably curb Dengue transmission rates even in the face of evolving climate patterns. Beyond immediate response mechanisms, African nations are also investing in long-term climate adaptation strategies within their health policies. This includes infrastructure enhancements to

withstand climate-related challenges, capacity-building initiatives to equip healthcare professionals with the skills to address climate-related health risks, and cross-sectoral collaborations to integrate climate change considerations into broader health planning frameworks[30].

Africa's contribution to Dengue Fever epidemiology lies in its diverse ecological settings, which host various Dengue virus serotypes and vector species. While historically considered less affected than other regions, Africa has seen an increase in Dengue cases and outbreaks in recent years. This has contributed valuable data to global Dengue epidemiology, enhancing understanding of the disease's transmission dynamics and risk factors.

Amidst obvious challenges, African resilience in the fight against Dengue Fever has continues to grow driven by a commitment to protect public health and improve the well-being of communities across the continent. Its contributions to global health are significant. By leveraging its expertise, resources, and collaborative networks, Africa plays a vital role in the global fight against Dengue Fever and contributes to the broader goal of improving health outcomes for all[24,29,30].

Conclusion

Advancing dengue fever preparedness in Africa requires a multi-faceted approach that addresses the unique challenges faced by the continent. By strengthening surveillance systems, building healthcare capacity, implementing vector control measures, promoting research and innovation, and fostering regional collaboration, African countries can enhance their ability to prevent and control dengue outbreaks.

Investing in dengue fever preparedness is not only essential for protecting public health but also for promoting sustainable development and resilience in the face of emerging infectious diseases. Addressing Dengue in Africa is not merely a regional imperative but a global health priority.

By prioritizing Dengue preparedness, investing in capacity building, strengthening health systems, fostering research and innovation, fostering regional collaboration, and advocating for political commitment and resource allocation, Africa can enhance its resilience against Dengue and contribute significantly to the global fight against this debilitating disease. Together, we can forge a future where Dengue ceases to be a threat to public health, both in Africa and beyond.

Africa's public health resilience in the face of Dengue fever is commendable, yet challenges persist. By addressing these challenges and capitalizing on emerging prospects, Africa can further strengthen its contribution to the global fight against Dengue fever.

Through sustained investment, collaboration, and innovation, Africa has the potential to not only mitigate the impact of Dengue fever within its borders but also serve as a beacon of inspiration for other regions facing similar health challenges.

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