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Narrative Review of Malaria Control Measures in Rural Sub-Saharan Africa: A Systematic Review with a Focus on Egbedore LGA, Osun State, Nigeria

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ABSTRACT

Malaria remains one of the most significant health challenges globally, especially in sub-Saharan Africa, where it continues to impose a substantial burden on public health systems and economies. This narrative review aims to assess the effectiveness of malaria control measures in rural regions, with a particular focus on Egbedore Local Government Area (LGA) in Osun State, Nigeria. The review examines the implementation of Insecticide-Treated Nets (ITNs), Indoor Residual Spraying (IRS), Seasonal Malaria Chemoprevention (SMC), and the RTS,S/AS01 malaria vaccine within rural contexts. Despite the ongoing deployment of these interventions, persistent challenges such as inconsistent ITN usage, limited IRS coverage, low vaccine uptake, and logistical constraints continue to undermine the effectiveness of malaria control efforts in rural areas. Furthermore, the review highlights the social, economic, and ethical considerations surrounding the implementation of these measures in rural communities. Through a detailed examination of the situation in Egbedore LGA, the review identifies gaps in the current malaria control strategies and discusses the critical need for community engagement, improved healthcare infrastructure, and integrated approaches to reduce malaria transmission. This review provides an in-depth analysis of the local barriers and opportunities for improving malaria control efforts in rural Nigeria and similar settings across sub-Saharan Africa

Keywords: Malaria control measures, Rural sub-Saharan Africa, Narrative review

1. INTRODUCTION

Malaria remains one of the leading causes of morbidity and mortality globally, particularly in sub-Saharan Africa, where the disease burden is most severe. According to the World Health Organization (WHO), malaria causes 94% of global cases and deaths in the region, with Nigeria being the country with the largest number of cases, accounting for nearly 27% of global malaria infections (Oladunni et al., 2023; World Health Organization, 2024). Despite significant progress in malaria control through interventions like insecticide-treated nets (ITNs), indoor residual spraying (IRS), seasonal malaria chemoprevention (SMC), and the RTS,S/AS01 malaria vaccine, the disease remains endemic, especially

in rural areas where health infrastructure is weak and access to medical services is limited (Omale et al., 2024).

This narrative review focuses on Egbedore Local Government Area (LGA) in Osun State, Nigeria, as a representative case for understanding malaria control challenges in rural settings. Egbedore LGA is characterized by high malaria prevalence rates, especially during the rainy season, and it presents a unique opportunity to evaluate the effectiveness of malaria control measures and identify barriers that hinder their optimal implementation. In Egbedore, malaria prevalence is estimated at 35-50%, with seasonal peaks affecting children under five and pregnant women the most (Rotimi et al., 2024). The review aims to assess the role of various interventions in reducing malaria transmission and identify the socio-economic, cultural, and infrastructural factors that influence their success.

1.1 Malaria Control Measures: An Overview

Malaria control strategies are central to reducing the global burden of the disease, aiming to prevent transmission, decrease morbidity and mortality, and ultimately achieve disease elimination. These strategies target different stages of the malaria parasite lifecycle, focusing on the vector, the host, and transmission dynamics. Key malaria control measures include vector control, chemoprevention, and vaccination, each of which has contributed to varying degrees of success in different regions. In rural areas of sub-Saharan Africa, where the burden is highest, a combination of these interventions is critical to effectively reduce malaria transmission.

Insecticide-treated nets (ITNs) remain one of the most widely used and effective tools in malaria prevention. ITNs work by providing a physical barrier to mosquitoes, preventing bites during the night when mosquitoes are most active. The nets are treated with insecticides, which not only repel mosquitoes but also kill those that come into contact with the treated surface. Studies have consistently demonstrated the effectiveness of ITNs in reducing malaria transmission by up to 50% in areas with high coverage, especially in high-transmission regions (Atolagbe et al., 2024). However, the benefits of ITNs are not fully realized in areas where usage is inconsistent. Factors such as heat discomfort, poor maintenance of nets, and lack of re-treatment contribute to low adherence to ITN usage, despite their availability. In rural Nigeria, including Egbedore LGA, ITN ownership is high, yet the consistent use remains a challenge (Rotimi et al., 2024). The gap between ownership and consistent usage highlights the need for complementary strategies, such as community-based health education and behavioral interventions to maximize the effectiveness of ITNs.

Another crucial vector control strategy is Indoor Residual Spraying (IRS), which involves applying insecticides to the walls and ceilings of homes, where mosquitoes tend to rest after feeding. IRS is highly effective in reducing malaria transmission by killing mosquitoes that come into contact with treated surfaces. In settings with adequate IRS coverage, it can reduce mosquito populations significantly and lead to a marked decline in malaria cases. However, the sustainability of IRS programs is challenged by factors such as high operational costs, the need for frequent reapplication of insecticides, and logistical barriers related to the distribution of insecticides in rural areas (Adeleke et al., 2022). In Egbedore LGA, as in many rural Nigerian communities, IRS coverage remains limited due to insufficient health infrastructure and funding constraints. Additionally, the emergence of insecticide resistance has compromised the effectiveness of IRS in some areas, making it imperative to explore alternative insecticides and integrated vector control approaches.

Seasonal Malaria Chemoprevention (SMC) has emerged as an important strategy for preventing malaria in children under five, particularly in regions with highly seasonal transmission. SMC involves the administration of antimalarial drugs to children during the peak transmission season, effectively reducing malaria incidence. The strategy has been shown to reduce malaria episodes by up to 75% in children, preventing both clinical malaria and severe cases. In areas with high malaria transmission, SMC has become a key component of malaria control programs, especially in high-risk populations (Kimbi et al., 2015; Adeniregun et al., 2024). However, challenges such as drug stockouts, irregular drug distribution, and poor coverage remain significant barriers to the widespread implementation of SMC in rural areas like Egbedore LGA (Odoemene et al., 2020). Additionally, community acceptance and adherence to the

drug regimen are crucial factors that determine the success of SMC, emphasizing the need for improved healthcare infrastructure and community outreach programs (Adeniregun et al., 2024).

The introduction of RTS,S/AS01, the first malaria vaccine recommended by the World Health Organization (WHO) for children aged five months and older, has provided a new tool in the fight against malaria (WHO, 2024). The vaccine targets the sporozoite stage of the *Plasmodium falciparum* parasite, providing partial protection against malaria. Clinical trials and pilot programs in Malawi, Ghana, and Kenya have demonstrated that the RTS,S/AS01 vaccine reduces malaria incidence by approximately 30-50% (Venkatesan, 2024; Olusoji et al., 2023). Although this represents a significant achievement, the partial efficacy of the vaccine means that it cannot be relied upon as a standalone intervention but must be used in combination with other measures such as ITNs and IRS. In rural regions like Egbedore LGA, where vaccine distribution systems are often inefficient, the rollout of the RTS,S/AS01 vaccine faces logistical challenges, including poor cold chain systems, vaccine stockouts, and community reluctance (Oladunni et al., 2023). As such, while the vaccine holds promise, its impact will be maximized only through coordinated delivery alongside other malaria control interventions (Adeniregun et al., 2023).

The integration of these malaria control measures—ITNs, IRS, SMC, and vaccines—forms the backbone of malaria control programs in sub-Saharan Africa. However, the effectiveness of these measures in rural settings is contingent upon overcoming several barriers to implementation and adherence. These barriers include geographic isolation, low healthcare access, socio-cultural beliefs, and logistical challenges. In regions like Egbedore LGA, where malaria prevalence remains high despite the presence of these interventions, addressing these barriers is crucial for the success of malaria control programs.

Malaria control measures such as ITNs, IRS, SMC, and vaccination play vital roles in the fight against malaria. However, to effectively reduce malaria transmission in rural sub-Saharan Africa, including Egbedore LGA, it is essential to integrate these strategies, enhance community participation, and address the logistical, cultural, and health system barriers that hinder their success. The evolution of malaria control will require an ongoing commitment to improving health systems, infrastructure, and public health education, while also exploring new technologies and innovative approaches to eliminate malaria.

1.2 Implementation of Malaria Control Measures in Africa

The implementation of malaria control measures in sub-Saharan Africa, particularly in rural regions, presents significant challenges. Despite substantial investments in public health interventions, malaria remains one of the deadliest diseases, primarily due to the difficulty of reaching and sustaining effective malaria control strategies in rural areas. These challenges are compounded by issues such as geographic isolation, cultural resistance, and limited healthcare infrastructure, all of which hinder the effectiveness of malaria control measures.

1.2.1 Rural Sub-Saharan Africa

In rural sub-Saharan Africa, where malaria transmission is highest, several barriers impede the effective deployment of malaria control programs. Geographic isolation is one of the most significant challenges, as many rural areas are poorly connected by roads and infrastructure, making it difficult for health services to reach remote communities. This isolation hampers the delivery of essential malaria interventions, such as Insecticide-Treated Nets (ITNs) and Indoor Residual Spraying (IRS), both of which rely on efficient distribution networks and regular monitoring. Transport challenges and cost are often the reasons these interventions are not implemented at the scale necessary to curb malaria transmission (Adeleke et al., 2022).

Another significant challenge in rural areas is cultural resistance to health interventions. In many parts of rural Africa, traditional beliefs and misconceptions about malaria affect the willingness of communities to adopt malaria control measures. For example, some communities are reluctant to use ITNs, believing that mosquito bites during the night are harmless, or that the nets are unnecessary (Odoemene et al., 2020). The introduction of malaria vaccines has faced similar challenges. Vaccine hesitancy in rural areas, driven by misinformation and fear of side effects, has slowed down efforts to reduce malaria transmission. As noted by Venkatesan (2024) and Oladunni et al. (2023), addressing these cultural barriers requires

sustained community engagement and the incorporation of local knowledge into malaria prevention programs.

Moreover, limited healthcare facilities and a shortage of skilled health workers in rural areas exacerbate the challenges of implementing malaria control measures. In regions with few health posts, it is difficult to administer Seasonal Malaria Chemoprevention (SMC), ensure the proper use of ITNs, and conduct effective IRS campaigns. According to Talabi et al. (2024), rural health systems in sub-Saharan Africa are often overstretched and lack the resources to deliver interventions at the scale required to tackle malaria effectively. Even when programs are implemented, the quality of service delivery remains a concern, as many rural communities have limited access to trained healthcare workers capable of conducting proper health education, distributing malaria prevention tools, and ensuring adherence to malaria control programs.

1.2.2 Nigeria, Osun State, Egbedore LGA

In Nigeria, the National Malaria Control Program (NMCP) is responsible for leading the country's efforts to reduce malaria prevalence. The program emphasizes the distribution of Insecticide-Treated Nets (ITNs), Indoor Residual Spraying (IRS), and Seasonal Malaria Chemoprevention (SMC). While these efforts have been successful in urban areas, rural regions like Egbedore LGA, located in Osun State, continue to face challenges that limit the effectiveness of these strategies.

One of the primary barriers to effective malaria control in Egbedore LGA is the limited coverage of IRS. IRS is more commonly used in urban centers where mosquito breeding sites are more concentrated, and the logistical support for spraying campaigns is more accessible. However, in rural settings, the cost of insecticides, the need for trained personnel, and the difficulty of reaching remote communities limit the application of IRS. According to Rotimi et al. (2024), while IRS coverage has improved in certain parts of Osun State, Egbedore LGA still faces challenges in ensuring that IRS reaches all at-risk households.

Similarly, while ITN ownership is relatively high in Egbedore LGA (approximately 50%), the usage rates of ITNs remain suboptimal. Many households in rural Nigeria, including in Egbedore LGA, report owning nets but failing to use them consistently. Factors such as mosquito resistance to insecticides, discomfort from using the nets during hot nights, and lack of proper maintenance contribute to the underuse of ITNs (Kimbi et al., 2015; Oladele et al., 2019). Moreover, there is a lack of community awareness regarding the proper use of ITNs, which further diminishes their effectiveness as a malaria control tool.

In addition, Seasonal Malaria Chemoprevention (SMC), which has been shown to be highly effective in preventing malaria in children under five, is still not widely implemented in rural Nigeria, particularly in Egbedore LGA. While SMC has been demonstrated to reduce malaria incidence by up to 75% during the peak transmission season, its rollout is hindered by poor drug distribution systems, lack of community trust in the intervention, and logistical barriers such as drug stockouts and irregular administration schedules (Kimbi et al., 2015; Odoemene et al., 2020). Despite the proven efficacy of SMC, its coverage remains inconsistent in rural areas, where health infrastructure is weak and local healthcare workers are often undertrained or unavailable to administer the treatment properly.

Despite these challenges, malaria control efforts in Egbedore LGA have not been entirely ineffective. The NMCP and local health authorities have made strides in ITN distribution and SMC implementation, but as Rotimi et al. (2024) highlight, malaria prevalence in Egbedore LGA remains high, particularly during the rainy season when transmission peaks. This persistent malaria burden underscores the need for more effective implementation of control measures, including improving health infrastructure, increasing community engagement, and strengthening logistics and supply chains for malaria interventions.

The implementation of malaria control measures in rural sub-Saharan Africa faces significant barriers, including geographic isolation, poor infrastructure, cultural resistance, and limited healthcare resources. In rural Nigeria, particularly in Egbedore LGA, the challenges are further compounded by the underutilization of proven interventions like IRS, ITNs, and SMC. While there have been improvements in malaria control efforts, such as increased ITN distribution, suboptimal usage of these tools and logistical barriers continue to hinder their effectiveness. To reduce the malaria burden in rural Nigeria and

other similar regions, it is essential to address the health system deficiencies, logistical challenges, and community acceptance issues that undermine the success of these interventions.

1.3 Impact on Malaria Burden in Africa, Nigeria, and Egbedore LGA

Malaria continues to exert a significant health burden across sub-Saharan Africa, despite the introduction of various control measures such as Insecticide-Treated Nets (ITNs), Indoor Residual Spraying (IRS), Seasonal Malaria Chemoprevention (SMC), and the introduction of malaria vaccines. However, the persistence of the disease, particularly in rural regions, reflects substantial challenges in the full implementation and effectiveness of these measures, especially during peak transmission periods. Malaria control efforts have achieved some success in urban areas, but rural communities still face major hurdles due to limited healthcare infrastructure, resources, and access to prevention tools (Venkatesan, 2024). This situation underscores the need for more targeted and integrated approaches to malaria control, tailored to the specific needs of rural populations.

1.3.1 Malaria Burden in Sub-Saharan Africa

Sub-Saharan Africa remains the epicenter of the global malaria burden, contributing approximately 94% of the total global malaria cases and deaths (World Malaria Report, 2024). This region, which is home to more than 400 million people, faces an ongoing struggle to control malaria, particularly in high-transmission areas where mosquitoes are abundant and healthcare infrastructure is often inadequate (Olusoji et al., 2023). Despite significant advancements in control measures, including the distribution of ITNs, widespread IRS applications, and chemoprevention programs, the malaria burden remains disproportionately high due to issues such as vector resistance, poor program coverage, and implementation inefficiencies (Bhatt et al., 2015). Oladunni et al. (2023) further underscore that malaria continues to place a substantial burden on public health systems in many African countries, draining critical resources and hindering economic development, as the disease diverts funds and labor away from other sectors.

1.3.2 Malaria Burden in Nigeria

As the country with the highest number of malaria cases in the world, Nigeria accounts for 27% of global malaria cases (World Malaria Report, 2024). Despite national efforts such as the National Malaria Control Program (NMCP), malaria prevalence remains high, particularly in rural areas where the coverage of malaria interventions like ITNs, IRS, and SMC is still insufficient. While ITN ownership in Nigeria is relatively high, studies have shown that usage rates remain low due to cultural perceptions, discomfort, and a lack of awareness about proper usage (Adeleke et al., 2022). In rural Nigeria, these challenges are compounded by limited access to healthcare facilities, making it difficult for people to access diagnosis and treatment on time (Odoemene et al., 2020).

Efforts to control malaria in Nigeria have resulted in some progress. For instance, Osun State has made strides in reducing malaria mortality through active malaria control programs, although the state still faces substantial malaria-related challenges, particularly in its rural areas. According to Oladele et al. (2019), Osun State records relatively low malaria mortality rates compared to other Nigerian states, but prevalence remains high, with a marked increase during the rainy season. The rainy season facilitates higher mosquito breeding, leading to seasonal peaks in malaria transmission, further highlighting the challenges of controlling malaria during certain periods of the year.

1.3.3 Malaria Burden in Osun State and Egbedore LGA

Malaria remains a significant health issue in Osun State, with prevalence estimates ranging from 30–40% (Odoemene et al., 2020). However, in Egbedore LGA, a local government area in southern Osun State, the situation is more concerning. Despite the distribution of ITNs, IRS, and the introduction of SMC, malaria prevalence in Egbedore LGA continues to fluctuate between 35–50%, with significant seasonal peaks during the rainy season. As reported by Rotimi et al. (2024), seasonal malaria outbreaks in Egbedore demonstrate the ineffectiveness of current malaria control measures during high-transmission months. Despite substantial investments in malaria control interventions, seasonal peaks persist due to insufficient coverage and inconsistent usage of the available preventive measures.

In Egbedore LGA, several challenges continue to hinder the full impact of malaria control programs. For example, while ITN ownership is relatively high in the area, consistent usage remains low. Many households that own ITNs fail to use them regularly, citing factors such as discomfort, lack of re-treatment, and insufficient understanding of the net's importance (Odoemene et al., 2020). Similarly, the implementation of Indoor Residual Spraying (IRS) in Egbedore LGA has been limited due to high costs and logistical barriers. IRS has been shown to be effective in reducing mosquito populations, but its widespread application remains challenging in rural areas due to insufficient funding and lack of trained personnel to carry out the spraying campaigns (Adeleke et al., 2022).

Seasonal Malaria Chemoprevention (SMC), which has been shown to reduce malaria incidence by up to 75% in children under five, has also been underutilized in Egbedore LGA. The lack of effective distribution networks, inconsistent supply of antimalarial drugs, and poor community engagement are significant barriers to the successful implementation of SMC (Kimbini et al., 2015). As Rotimi et al. (2024) note, the lack of community awareness about the benefits of SMC has contributed to underutilization, especially in rural settings where there is often limited trust in government-led health programs. In Egbedore LGA, as in many rural areas, the seasonal surge in malaria cases remains a major public health challenge.

Furthermore, despite the introduction of malaria vaccines such as RTS,S/AS01, the rollout of these vaccines in Egbedore LGA remains limited, and coverage is insufficient to make a substantial impact on malaria transmission. Venkatesan (2024) emphasizes that while the RTS,S vaccine has shown partial efficacy, logistical challenges in vaccine distribution, cold chain management, and vaccine hesitancy hinder its effectiveness in rural regions like Egbedore LGA.

2.1 Efforts to Control Malaria in Nigerian Osun State and Egbedore Local Government Area

Nigeria has implemented several large-scale malaria control programs, particularly in urban centers, to combat the persistent malaria burden. The National Malaria Control Program (NMCP) has focused on Insecticide-Treated Nets (ITNs), Indoor Residual Spraying (IRS), Seasonal Malaria Chemoprevention (SMC), and more recently, the introduction of malaria vaccines. Despite these efforts, rural regions like Egbedore Local Government Area (LGA) in Osun State face substantial barriers to effective malaria control. These barriers include limited access to health facilities, inconsistent distribution of ITNs, and logistical challenges in the implementation of IRS and other interventions. While malaria control efforts have achieved some success in urban centers, their effectiveness is undermined in rural areas by infrastructural and social challenges.

2.1.1 Limited Access to Health Facilities and Diagnostic Tools

A major constraint to malaria control in Egbedore LGA is the limited access to healthcare facilities and diagnostic tools. Rural communities in the region often lack adequate healthcare infrastructure, and access to diagnostic services such as malaria testing is restricted. According to Odoemene et al. (2020), polyparasitism, where malaria coexists with other intestinal parasite infections among children, is a significant concern in Egbedore, further complicating accurate diagnosis and treatment. Many residents in Egbedore LGA rely on local remedies or unqualified health providers, which leads to delayed diagnosis and treatment, resulting in prolonged malaria illness and higher mortality rates.

The lack of skilled healthcare workers in rural regions compounds this issue. In Egbedore LGA, as documented by Adeyemo et al. (2015), health information dissemination, such as malaria prevention and home management, often depends on health officers and community-based health workers. However, these resources are limited, and rural dwellers often receive insufficient health education, reducing the impact of malaria control programs. Furthermore, mothers of children under five often lack the skills or knowledge to properly manage malaria at home, as evidenced by Adeyemo's (2015) study on nurse-led health education in Egbedore LGA.

2.1.2 Inconsistent Distribution of ITNs

While Insecticide-Treated Nets (ITNs) have been widely distributed as part of the national malaria control efforts, their distribution in rural areas like Egbedore LGA is often inconsistent, especially during the

rainy season, when malaria transmission peaks. Odoemene et al. (2020) point out that while ITN ownership rates in Egbedore LGA are relatively high, the usage of these nets remains low due to factors such as discomfort, lack of maintenance, and poor community engagement. Additionally, the lack of a regular supply chain for ITNs, especially in remote parts of Egbedore, has led to gaps in coverage and inconsistent access for those who are most vulnerable to malaria, such as children under five and pregnant women.

Studies have shown that community-based health education can improve the adherence to ITN use. Adeyemo et al. (2015) found that nurse-led health education programs targeting mothers of young children in Egbedore LGA were effective in improving home management and prevention practices. However, inadequate funding, logistical challenges, and lack of local health education programs in rural communities hinder the sustained effectiveness of ITN distribution.

2.1.3 Challenges in Implementing IRS

The application of Indoor Residual Spraying (IRS) is an important vector control strategy in malaria prevention, and it has been proven effective in reducing mosquito populations and malaria transmission. However, Egbedore LGA faces significant challenges in the implementation of IRS, primarily due to budgetary constraints and a lack of trained personnel. The high costs of insecticides, coupled with the poor road network and geographic isolation of rural areas, prevent IRS from being applied at a scale sufficient to control malaria transmission during the rainy season (Adeleke et al., 2022).

Odoemene et al. (2020) highlighted the fact that while IRS has shown positive results in urban centers, the high costs and lack of technical expertise have led to its underutilization in Egbedore LGA. Additionally, the seasonal nature of malaria transmission in Egbedore means that the application of IRS must be timed carefully, requiring frequent respraying during the peak months of mosquito activity. The logistics of timely and efficient IRS implementation in rural communities continue to be an insurmountable challenge, making it difficult to sustain effective malaria control over time.

The efforts to control malaria in Nigeria, particularly in Egbedore LGA, have faced several obstacles despite the implementation of strategies like ITNs, IRS, and SMC. In rural regions, Egbedore LGA in particular, these interventions face significant challenges, such as limited healthcare infrastructure, low usage of ITNs, and inconsistent IRS coverage. The lack of effective distribution mechanisms and inadequate health education continue to hinder the success of these interventions, particularly during seasonal peaks when transmission rates are highest.

To address these challenges, a multi-faceted approach is required, combining improved healthcare access, stronger community engagement, and targeted health education to enhance malaria prevention and control. Efforts to strengthen health infrastructure, train healthcare workers, and improve logistical support for malaria control programs will be critical to reducing the malaria burden in Egbedore LGA and other rural communities across Osun State and Nigeria.

3.1 Global, National, and Local Implications

The fight against malaria has broad implications that extend beyond the health sector and permeate into economic, social, and developmental domains. Malaria control is critical not only in improving the health status of affected populations but also in contributing to global development goals, alleviating economic burdens, and reducing poverty in endemic regions. From the global stage to national and local levels, the impact of malaria control efforts resonates across various sectors of society.

3.1.1 Global Implications

At the global level, malaria control plays a pivotal role in achieving the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being), SDG 1 (No Poverty), and SDG 8 (Decent Work and Economic Growth). The efforts to reduce malaria incidence and ultimately eradicate the disease are essential to improving global health equity and ensuring that people in low-income countries have the opportunity to lead healthy, productive lives. As the World Health Organization (WHO) highlights in its World Malaria Report (2024), malaria continues to be one of the leading causes of preventable death worldwide, especially in sub-Saharan Africa, where it is the leading cause of morbidity

and mortality. Malaria disproportionately affects poor and marginalized communities, and thus, efforts to control the disease are crucial for achieving a fairer distribution of health and economic opportunities on a global scale.

In addition to health, malaria has economic implications at the global level. The Global Fund to Fight AIDS, Tuberculosis and Malaria estimates that the economic burden of malaria exceeds \$12 billion annually in Africa alone due to healthcare costs and lost productivity. The economic cost of malaria on a global scale is substantial, and controlling the disease is therefore integral to the global economy. As such, malaria control is not just a health issue but a key driver of economic development in regions most affected by the disease. For the international community, investing in malaria control is both a moral imperative and an economic strategy that benefits global stability, health, and prosperity.

3.1.2 National Implications (Nigeria)

At the national level, Nigeria's malaria burden places a significant strain on the economy, with estimates suggesting that malaria-related costs in Nigeria total billions of dollars annually. According to Oladunni et al. (2023), malaria-related costs include healthcare expenditures for diagnosis, treatment, and hospital admissions, as well as lost productivity due to absenteeism from work and school. The World Bank has noted that malaria's economic toll on the Nigerian economy can be seen in the reduced workforce productivity, especially in agricultural sectors where farmers and laborers are most vulnerable. The disease also significantly affects education outcomes, as children suffering from malaria are often absent from school, which contributes to lower educational attainment in malaria-endemic areas (Kimbi et al., 2015).

Additionally, malaria is a major contributor to poverty in Nigeria. The disease prevents families from escaping poverty by draining resources from households and reducing the ability of adults to work and children to learn. According to the National Malaria Control Program (NMCP), the cost of treatment for malaria, combined with the lost wages from illness, means that affected households often fall into a cycle of poverty (Oladunni et al., 2023). The economic burden of malaria in Nigeria is compounded by inequities in healthcare access, particularly in rural areas like Egbedore LGA, where healthcare services are scarce or underfunded. In Nigeria, malaria control is not only a public health issue but a key driver of economic stability, requiring significant investment in health systems to ensure economic recovery and growth.

3.1.3 Local Implications (Egbedore LGA, Osun State)

At the local level, the malaria burden in Egbedore Local Government Area (LGA), Osun State, presents critical implications for both public health and economic development. Despite national malaria control efforts, the persistent high prevalence of malaria in Egbedore LGA highlights the limited effectiveness of current interventions in rural regions. As reported by Odoemene et al. (2020), the high malaria prevalence in Egbedore is linked to seasonal peaks, with children under five and pregnant women disproportionately affected by the disease. These vulnerable populations suffer from high morbidity, leading to frequent hospital visits, school absenteeism, and reduced work productivity. This not only impacts the health of individuals but also places a burden on local health facilities, many of which are already under-resourced and overstretched (Adeyemo et al., 2015).

The direct health impacts of malaria in Egbedore LGA exacerbate the cycle of poverty in the region. Families affected by malaria often incur significant out-of-pocket costs for treatment, leading to financial strain. Children under five, who are most vulnerable to severe malaria, experience delayed development due to frequent illness, while pregnant women face complications during pregnancy, including miscarriage, premature delivery, and low birth weight (Odoemene et al., 2020). These health issues hinder the human capital development in the community, further perpetuating economic stagnation.

Moreover, the economic consequences of malaria in Egbedore LGA are substantial. Malaria-related absenteeism from school and work results in lost productivity, which directly affects local businesses, agriculture, and education. Agricultural productivity, a primary source of income for many families in Egbedore LGA, is particularly affected, as sick workers cannot engage in farming activities during the

crucial planting and harvesting seasons. This leads to lower yields and reduced income, perpetuating the cycle of poverty (Adeyemo et al., 2015).

Finally, the lack of infrastructure and inconsistent distribution of malaria prevention tools, such as ITNs and SMC, further complicates the situation. Despite efforts by the government and NGOs, the reach of malaria control interventions in Egbedore LGA is still limited. As highlighted by Rotimi et al. (2024), the seasonal peaks in malaria cases are a testament to the inefficiency of current interventions, indicating that more localized and integrated approaches are needed to reduce transmission rates effectively.

The implications of malaria control efforts are far-reaching, affecting not only health outcomes but also economic stability and social development. At the global level, malaria control is essential for achieving SDG 3 on health and SDG 1 on poverty reduction, contributing to global health equity. Nigeria's malaria burden remains a significant economic strain, draining billions from the country's economy through healthcare costs and lost productivity. At the local level, in areas like Egbedore LGA, the malaria burden exacerbates poverty, economic stagnation, and poor health outcomes for vulnerable populations, especially children and pregnant women. Addressing these local challenges requires improved malaria control strategies that combine better healthcare infrastructure, community engagement, and targeted interventions to reduce malaria transmission and improve public health.

4.1 Progress of Malaria Control in Africa, Nigeria, Osun State, and Egbedore LGA Following Implementation

Malaria control efforts across sub-Saharan Africa, including Nigeria and Osun State, have shown varying levels of success. In Egbedore LGA, there has been a slight decline in malaria prevalence following the implementation of key malaria control measures such as Insecticide-Treated Nets (ITNs), Seasonal Malaria Chemoprevention (SMC), and the RTS,S malaria vaccine. However, several persistent challenges continue to hinder further progress.

At the national level, Nigeria's malaria control programs, led by the National Malaria Control Program (NMCP), have contributed to a gradual decline in malaria prevalence, especially in urban areas. ITN distribution has been a cornerstone of Nigeria's malaria control strategy, leading to improved coverage across many regions. According to Venkatesan (2024), ITNs remain a widely used tool, with coverage increasing steadily. However, challenges persist in ensuring consistent ITN usage, particularly in rural communities such as Egbedore LGA, where factors such as lack of awareness, cultural resistance, and discomfort with the nets have contributed to low adherence (Rotimi et al., 2024). Despite widespread distribution, ITN usage remains inconsistent, especially during high-transmission months when malaria prevalence spikes during the rainy season.

The introduction of Seasonal Malaria Chemoprevention (SMC) has been a significant step in reducing malaria incidence, particularly among children under five, who are most vulnerable to the disease. SMC has shown substantial efficacy in reducing malaria cases during the peak transmission period, with some studies reporting a 75% reduction in cases (Kimbi et al., 2015). However, in Egbedore LGA, the implementation of SMC has been suboptimal, with issues such as irregular drug distribution, poor community mobilization, and logistical constraints hindering its full effectiveness (Odoemene et al., 2020). The lack of effective distribution networks and the limited reach of SMC programs in rural regions contribute to gaps in coverage and reduced impact.

Similarly, the use of Indoor Residual Spraying (IRS), which has been proven effective in urban centers, has faced significant challenges in rural areas like Egbedore LGA. IRS has not been widely applied due to budgetary constraints, lack of trained personnel, and the high costs of insecticides required for large-scale spraying campaigns (Adeleke et al., 2022). As a result, IRS coverage in Egbedore LGA remains limited, and its impact on malaria transmission is insufficient, especially during peak transmission periods.

The introduction of the RTS,S malaria vaccine in pilot programs has marked a significant development in the fight against malaria, especially for children under five. However, its deployment in Egbedore LGA is still in its early stages, and coverage remains limited due to logistical barriers, cold chain issues, and community reluctance to accept the vaccine (Venkatesan, 2024). Despite its promise, the RTS,S vaccine

is still being rolled out in a phased approach, and its full potential in Egbedore LGA and other rural areas is yet to be realized. In summary, while malaria control measures such as ITNs, SMC, and the RTS,S vaccine have shown modest progress in reducing malaria prevalence in Egbedore LGA, several persistent challenges remain. Inconsistent ITN usage, limited IRS coverage, and underutilization of SMC continue to undermine the effectiveness of these interventions, particularly in rural communities. Addressing these challenges requires more localized strategies, improved health system infrastructure, better community engagement, and effective distribution networks to enhance the reach and impact of malaria control efforts in rural Nigeria.

5.0 Challenges and Opportunities for Global Deployment of Malaria Control Programs

The global deployment of malaria control programs faces significant challenges, especially in rural areas. While Insecticide-Treated Nets (ITNs), Indoor Residual Spraying (IRS), and malaria vaccines like RTS,S have been central to malaria control strategies, rural regions often experience barriers that hinder the effectiveness of these interventions. However, these challenges also present unique opportunities for improving malaria prevention and control.

5.1 Challenges in Rural Areas

5.1.1. Inconsistent ITN Usage:

Although ITNs have proven to be a cornerstone of malaria control, their usage in rural areas remains inconsistent. Many households own ITNs, but they are often underused or improperly used, particularly during the rainy season when malaria transmission peaks. Factors such as discomfort, poor maintenance, and lack of awareness about the importance of regular use contribute to low adherence (Rotimi et al., 2024). Additionally, ITNs often deteriorate quickly due to wear and tear and lack of re-treatment, further reducing their effectiveness. Ensuring consistent usage and proper maintenance of ITNs is essential, yet difficult to achieve in rural settings where health education and access to resources are limited (Adeleke et al., 2022).

5.2. Limited IRS Coverage:

Indoor Residual Spraying (IRS), another critical malaria control strategy, faces challenges in rural areas due to logistical barriers and high costs. IRS requires frequent reapplication of insecticides to indoor surfaces, which is often unaffordable and difficult to implement in remote regions with limited access to insecticides and trained personnel. Additionally, the geographic isolation of rural communities, such as those in Egbedore LGA, makes it difficult to maintain consistent IRS coverage (Odoemene et al., 2020). The effectiveness of IRS is also threatened by the growing problem of insecticide resistance, which requires the constant introduction of new insecticide formulations, adding further complexity to its deployment in rural areas (Adeleke et al., 2022).

5.3. Low Vaccine Uptake:

The introduction of the RTS,S malaria vaccine offers a new tool in the fight against malaria, but its uptake in rural areas remains low. Vaccine hesitancy, due to cultural beliefs, misinformation, and fear of side effects, presents significant barriers to the widespread acceptance of the vaccine (Venkatesan, 2024). In rural Nigeria, where health literacy is often low and vaccine delivery infrastructure is weak, ensuring that the RTS,S vaccine reaches the most vulnerable populations—especially children under five—is a challenge. Furthermore, the cold chain requirements for the vaccine present logistical barriers in remote regions with unreliable power and transportation networks (Oladunni et al., 2023).

5.4 Opportunities for Improving Malaria Control in Rural Areas

5.4.1 Community Health Workers (CHWs):

One of the most promising opportunities to overcome the challenges of malaria control in rural areas is the increased utilization of Community Health Workers (CHWs). CHWs play a critical role in engaging communities, providing health education, and ensuring that malaria prevention methods such as ITNs and SMC are used properly. CHWs can distribute ITNs, conduct health education sessions, and administer treatment and SMC in hard-to-reach communities. Their local knowledge and trust within the community make them key players in overcoming the barriers to consistent malaria control. According to Adeyemo et

al. (2015), nurse-led health education programs in Egbedore LGA significantly improved malaria prevention and home management practices, highlighting the potential for CHWs to improve the adoption of malaria control measures in rural areas.

5.4.2. Mobile Health Technologies:

The advent of mobile health technologies offers an exciting opportunity to bridge gaps in malaria control in rural areas. Mobile phones can be used for malaria diagnosis, tracking prevalence, and providing health education in regions with limited access to healthcare facilities. Mobile health apps can help health workers track malaria cases, send reminders for medication adherence, and provide health education to remote populations. For instance, SMS-based systems can remind people to use ITNs or take antimalarial drugs during peak transmission seasons, improving adherence rates (Rotimi et al., 2024). Furthermore, mobile diagnostic tools could facilitate early diagnosis and treatment, even in areas where traditional diagnostic infrastructure is lacking. These technologies can also play a vital role in monitoring and evaluating the success of malaria control interventions, making them an essential component of sustainable malaria control programs.

While there are significant challenges in deploying malaria control measures in rural areas, including inconsistent ITN usage, limited IRS coverage, and low vaccine uptake, these challenges also present valuable opportunities for innovation. The deployment of Community Health Workers (CHWs) and the use of mobile health technologies can address many of the barriers to effective malaria control in rural regions. Through the optimal deployment of these opportunities, malaria control programs can be more effectively tailored to local needs and contextual realities, leading to improved malaria outcomes in rural areas. However, investing in infrastructure, education, and community engagement will be critical to overcoming the persistent challenges and ensuring that malaria control interventions reach the most vulnerable populations.

6.0 Ethical, Social, and Economic Considerations

The implementation of malaria control programs presents several ethical, social, and economic challenges that must be carefully addressed to ensure their effectiveness and sustainability. These considerations are critical to achieving long-term public health goals and ensuring that malaria control interventions are equitable, accessible, and effective for all populations, particularly in rural communities where malaria burden is high.

6.1 Ethical Considerations

6.1.1. Informed Consent in Malaria Vaccine Trials:

One of the central ethical concerns in malaria vaccine trials is the issue of informed consent. In many rural areas where malaria vaccine trials are being conducted, it is crucial to ensure that participants fully understand the nature of the trials, the potential risks, and the benefits. Ethical principles require that participants voluntarily agree to participate in the trial, without any coercion or undue influence. In rural communities like Egbedore LGA, where health literacy may be lower, ensuring that participants comprehend the purpose of the trial and the possible side effects is paramount to maintaining ethical standards. As Venkatesan (2024) notes, community engagement and the provision of culturally appropriate information are essential for obtaining genuine informed consent, ensuring that the participants' rights are respected throughout the process.

6.1.2. Vaccine Equity:

Another major ethical concern is vaccine equity. Ensuring that the benefits of malaria vaccination reach all populations, particularly those in rural areas, is crucial. Rural communities often face barriers to accessing vaccines due to geographic isolation, poor infrastructure, and logistical challenges. In Egbedore LGA, the cold chain requirements for the RTS,S malaria vaccine can complicate its delivery and distribution, especially in hard-to-reach areas. Furthermore, cultural factors, such as vaccine hesitancy, can hinder vaccine acceptance in rural communities, exacerbating health disparities (Oladunni et al., 2023). To address these concerns, it is important to ensure that vaccination programs are equitable,

inclusive, and accessible to the most vulnerable populations, regardless of their geographical location or socio-economic status.

6.2 Social Considerations

6.2.1. Behavioral Change Communication (BCC):

One of the most critical social factors in malaria control is behavioral change communication (BCC). BCC aims to influence individuals' attitudes and behaviors toward malaria prevention methods such as ITNs, IRS, and SMC. In rural communities, where traditional beliefs and misconceptions about malaria and its prevention may be prevalent, effective BCC strategies are essential for increasing awareness and encouraging the consistent use of malaria prevention methods. Adeyemo et al. (2015) emphasize the importance of nurse-led health education in Egbedore LGA, highlighting that community health workers (CHWs) play a pivotal role in educating local populations about the importance of ITN usage and malaria prevention. Culturally tailored health messages and community-based interventions can help overcome barriers to malaria prevention, fostering positive behavior change and increasing the adoption of evidence-based practices.

Moreover, social determinants of health, such as gender norms, socioeconomic status, and educational levels, influence people's willingness and ability to adopt malaria control measures. For example, in Egbedore LGA, mothers and caregivers of young children are often the primary decision-makers regarding ITN use and malaria treatment. Therefore, targeting women and empowering them with the knowledge and resources to manage malaria prevention at the household level can have a significant impact on reducing malaria transmission in the community.

6.2.2. Community Engagement and Trust:

Building community trust is another crucial element of malaria control. In rural communities, people are often more likely to adopt public health interventions when they trust the healthcare providers and believe that the interventions are beneficial to their well-being. Community participation in malaria control programs, such as engagement in the planning and implementation stages, can increase the effectiveness and sustainability of these programs. In Egbedore LGA, involving local leaders, health workers, and community members in the decision-making process can help ensure that the interventions are culturally appropriate and contextually relevant.

6.3 Economic Considerations

6.3.1. Economic Burden of Malaria:

The economic implications of malaria control are significant at both the national and local levels. Malaria imposes a substantial economic burden on Nigeria, costing the economy billions annually in terms of healthcare expenditures, lost productivity, and poverty-related costs. According to Oladunni et al. (2023), malaria-related absenteeism from work and school is a major factor contributing to economic stagnation, particularly in rural areas. The economic burden is particularly acute in Egbedore LGA, where families often face high out-of-pocket costs for malaria treatment, leading to a vicious cycle of poverty. Moreover, the disease burden on the workforce reduces productivity and hinders economic growth.

6.3.2. Long-Term Benefits of Malaria Control Investments:

Investing in malaria control measures offers significant long-term economic benefits. By reducing malaria-related morbidity and mortality, countries can experience increased workforce productivity and economic growth. The costs associated with malaria treatment and prevention are far outweighed by the economic gains that result from improved health outcomes. Studies have shown that for every dollar invested in malaria control, there is a return of approximately \$40 in economic benefits, primarily due to increased productivity and reduced healthcare costs (World Bank, 2024).

For Egbedore LGA, investing in malaria control would not only reduce malaria-related healthcare costs but also enhance economic productivity by enabling individuals to work and children to attend school regularly. This, in turn, could help break the cycle of poverty and contribute to broader community development.

6.3.3 Cost-Effectiveness of Malaria Control Interventions:

The cost-effectiveness of malaria control interventions such as ITNs, IRS, and SMC has been well documented. These measures are relatively low-cost and have high returns in terms of both health outcomes and economic productivity. According to Kimbi et al. (2015), SMC is one of the most cost-effective strategies for reducing malaria incidence among children, with substantial reductions in malaria-related morbidity and hospital admissions during the rainy season. Ensuring that these interventions are efficiently deployed in rural communities like Egbedore LGA can significantly reduce the long-term economic burden of malaria on both families and the national economy.

The ethical, social, and economic considerations in malaria control are interconnected and must be addressed to ensure the sustainability and effectiveness of malaria control programs. Ethical concerns, such as informed consent and vaccine equity, need to be prioritized to ensure that malaria control efforts respect individual rights and provide equal access to preventive measures. Social factors, including behavioral change communication and community engagement, are essential for increasing the acceptance of malaria prevention methods and ensuring consistent use. Economically, investing in malaria control not only reduces healthcare costs but also boosts economic productivity, leading to long-term economic growth and poverty reduction. Addressing these ethical, social, and economic factors will be key to the success of global malaria control programs, particularly in rural regions where the burden of the disease is highest.

7.1 Data Availability

No datasets were generated or analyzed during the current study.

7.2 Abbreviations

- CHMI: Controlled human malaria infection
- EMC: End Malaria Council
- EPI: Expanded program on immunization
- GSK: GlaxoSmithKline
- HCWs: Healthcare workers
- LMIC: Low- and middle-income countries
- MVIP: Malaria vaccine implementation programme
- NMCP: National Malaria Control Programs
- UNICEF: United Nations International Children's Emergency Fund
- WHO: World Health Organization
- WRAIR: Walter Reed Army Institute of Research

8.1 AUTHOR CONTRIBUTIONS

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9.1 CONFLICT OF INTEREST

The authors declare no conflict of interest.

9.2 ETHICS STATEMENT

No approval from the ethics committee of the University or an Institutional Review Board was sought for this study.

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