SSRG International Journal of Medical Science
ISSN: 2393–9117 / https://doi.org/10.14445/23939117/IJMS-V13I1P104

Volume 13 Issue 1, 21-30, Jan-Feb 2026

Original Article

Importance of Well Disposal of Mosquito Nets Around and Above the Beds in the Prevention of Malaria Transmission in Republic of Benin, West Africa

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Received: 16 December 2025 Revised: 19 January 2026 Accepted: 10 February 2026 Published: 28 February 2026

Abstract *- Background: In Benin, malaria continues to be endemic and the first major cause of morbidity and mortality among the most vulnerable groups, children under 5 years of age and pregnant women. Objective: The current study was aimed at investigating the importance of installing well mosquito nets around and above the beds in the prevention of malaria transmission. Material and methods: Four bedrooms corresponding to four houses were selected in each of two districts surveyed, which were the Lokossa and Dogbo districts, for adult mosquito collection in the morning in June 2024 during the great rainy season. Mosquitoes inside the nets were collected by electronic racket from 6 a.m. to 7 a.m in the locations of Adjakomey and Agnivèdji in Lokossa district and in the locations of Achitou and Foncomè in Dogbo district. The survey was done simultaneously in both districts for ten consecutive nights. All collected mosquitoes were put in netted plastic cups and transferred to the Laboratory (LaRPET) for identification of Anopheles gambaie mosquitoes. Then, the physiological status of the abdomen of Anopheles gambaie mosquitoes was determined. The diagnostic tests of the presence of the parasite Plasmodium falciparum within sick people, such as parasite density, were done in a Laboratory of Biomedical Analysis located in the study area. Results: The results showed that the mosquitoes collected in bedrooms where mosquito nets were not well-appointed were higher than those collected in bedrooms where mosquito nets were well-appointed. Almost all people who slept in the beds where blood-fed Anopheles gambiae were found were sick. Conclusion: It is important to install mosquito nets well around and above the beds before sleeping at night.*

Keywords *- Mosquito net, Bed, Anopheles gambaie, Malaria prevention, Benin.*

1. Introduction

Globally, in 2023, the number of malaria cases was estimated at 263 million, with an incidence of 60.4 cases per 1000 population at risk. This is an increase of 11 million cases from the previous year and a rise in incidence from 58.6 cases per 1000 population at risk in 2022. The WHO African Region continues to carry the heaviest burden of the disease, accounting for an estimated 94% of malaria cases worldwide in 2023. The WHO Eastern Mediterranean Region has experienced a 57% increase in incidence since 2021, rising to 17.9 cases per 1000 population at risk in 2023. [1]

Globally, in 2023, the number of deaths was estimated at 597,000, with a mortality rate of 13.7 per 100,000. The

number of malaria deaths and the mortality rate steadily decreased from 622,000 and 14.9 deaths per 100,000, respectively, in 2020. The WHO African Region continues to carry the heaviest burden of mortality, with 95% of estimated malaria deaths worldwide. [1]

Using mosquito nets as a protection against nuisance insects was practiced in historical times. [2] During World War II, Russian, German, and US armies treated bed nets and combat fatigues with residual insecticide to protect soldiers against vector-borne diseases (mainly malaria and leishmaniasis). [3] In the late 1970s, entomologists started using synthetic pyrethroids: their high insecticidal activity and low mammalian toxicity made them ideal for this purpose.

In the 1980s, studies of ITNs showed that pyrethroids were safe and that ITNs had an impact on various measures of mosquito biting (such as the proportion of mosquitoes successfully feeding on humans and the number of times a mosquito bit humans in one night). These studies showed that pyrethroids worked by both repelling and killing mosquitoes. In addition, researchers determined optimal doses of various insecticides with different materials. [4,5,6,7] The cost-effectiveness of ITNs has also been demonstrated. [8]

Given the part played by *Plasmodium falciparum* malaria as a direct and indirect cause of death in African children, the main public health question for ITNs is whether they reduce mortality in children.

The bed net is the most widely used as a malaria control measure all over the world and in Africa, particularly. In addition, it is important that after the distribution of Long-Lasting Insecticidal Nets (LLINs) by the National Malaria Control Programs (NMCPs) in countries at risk of malaria, many evaluations or assessments are conducted on these tools of prevention in order to evaluate their effectiveness.

Very few studies were published on the people's practice or behavior using bed nets in the prevention of malaria transmission in Benin**.** Therefore, there is a need to carry out new research for this purpose. The goal of this study was to investigate the importance of installing well mosquito nets around and above the beds in the prevention of malaria transmission in the Republic of Benin, West Africa.

2. Review of Literature

Insecticide-Treated Nets (ITNs) and Long-Lasting Insecticidal Nets (LLINs) are the primary interventions for preventing malaria in sub-Saharan Africa. [9,10] Nets accumulate holes through wear and tear during the course of everyday use, but the pyrethroid treatment continues to provide personal protection and to reduce vector capacity through excito-repellency and the killing of mosquitoes that contact the net. [11,12]

Household nets are inevitably subject to wear and tear, and several studies have documented the association between naturally damaged ITNs and mosquito blood-feeding rates. Before the advent of ITNs, Port and Boreham, in an experimental hut study of bed nets previously used by local Gambians, found a strong correlation between blood feeding and the number and size of holes. [13] Irish *et al*., in an experimental hut trial of treated nets against pyrethroid-resistant *Cx. Quinquefasciatus* mosquitoes found an association between the proportion of mosquitoes' blood feeding and the number of holes in the ITN. [14] Cross-sectional parasite prevalence surveys in Equatorial Guinea showed that children sleeping under intact ITNs were protected against infection with *Plasmodium falciparum* but that the level of protection progressively decreased as the nets' condition deteriorated. [15]

3. Materials and Methods

3.1. Study Area

The study area is located in the Republic of Benin (West Africa) and includes the departments of Mono and Couffo. Mono and Couffo departments are located in the south-western Benin, and the study was carried out more precisely in Lokossa and Dogbo districts (Figure 1). The southern borders of the Lokossa district are Athiémé and Houéyogbé districts. The northern border is the Dogbo district. The eastern border is the Bopa district, and the western border is the Togo Republic. The Lokossa district covered 260 km^2. Regarding the Dogbo district, the southern borders of this district are the Lokossa and Bopa districts. The northern border is the Djakotomey district. The eastern border is the Lalo district, and the western border of this district is the Togo Republic. The Dogbo district covered 475 km^2 and belongs to the geographic region of ADJA. The choice of the study site took into account the economic activities of populations, their usual protection practices against mosquito bites, and peasant practices to control farming pests. These factors were taken into account to investigate the importance of installing well mosquito nets around and above the beds in the prevention of malaria transmission in the Republic of Benin. Four seasons, two rainy seasons (March to July and August to November) and two dry seasons (November to March and July to August) characterize the Mono and Couffo departments. The temperature ranges from 25 to 30°C, with the annual mean rainfall between 900 and 1100 mm.

3.2. Field Mosquito Collection

Four bedrooms corresponding to four houses were selected for adult mosquito collection in the morning in June 2024 during the great rainy season in each of two districts surveyed, which were Lokossa in Mono department and Dogbo in Couffo department. Mosquitoes inside the bed nets were collected by an electronic racket (Figure 2) from 6 a.m. to 7 a.m in the locations of Adjakomey and Agnivèdji in Lokossa district and in the locations of Achitou and Foncomè in Dogbo district. The survey was done simultaneously in both

districts for ten consecutive nights. All collected mosquitoes were put in netted plastic cups and transferred to the Laboratory of Pluridisciplinary Research of Technical Teaching (LaRPET) in Normal High School of Technical Teaching (ENSET) of Lokossa for identification of *Anopheles gambaie* mosquitoes. Then, the physiological status of the abdomen of *Anopheles gambaie* mosquitoes was determined.

Fig. 1 Map of the Republic of Benin showing Lokossa and Dogbo districts surveyed

Fig. 2 Electronic rackets used during the mosquito collection in the field

3.3. Collected Mosquito Identification

Adult collected mosquitoes were identified to species based on morphological characters using identification keys. [16]

3.4. Diagnosis of Malaria Case Due to Plasmodium Falciparum

The diagnostic tests of the presence of the parasite *Plasmodium falciparum* within sick people, such as parasite density, were done in a Laboratory of Biomedical Analysis located in the study area.

3.5. Statistical Analysis

A chi-square test for proportion comparison was performed to compare the proportions of mosquito species related to each bedroom.

4. Results

The analysis of Figure 3 showed that some mosquito species were found in bedroom 3 in the Lokossa district and in bedroom 1 in the Dogbo district, despite the fact that they were well-appointed.

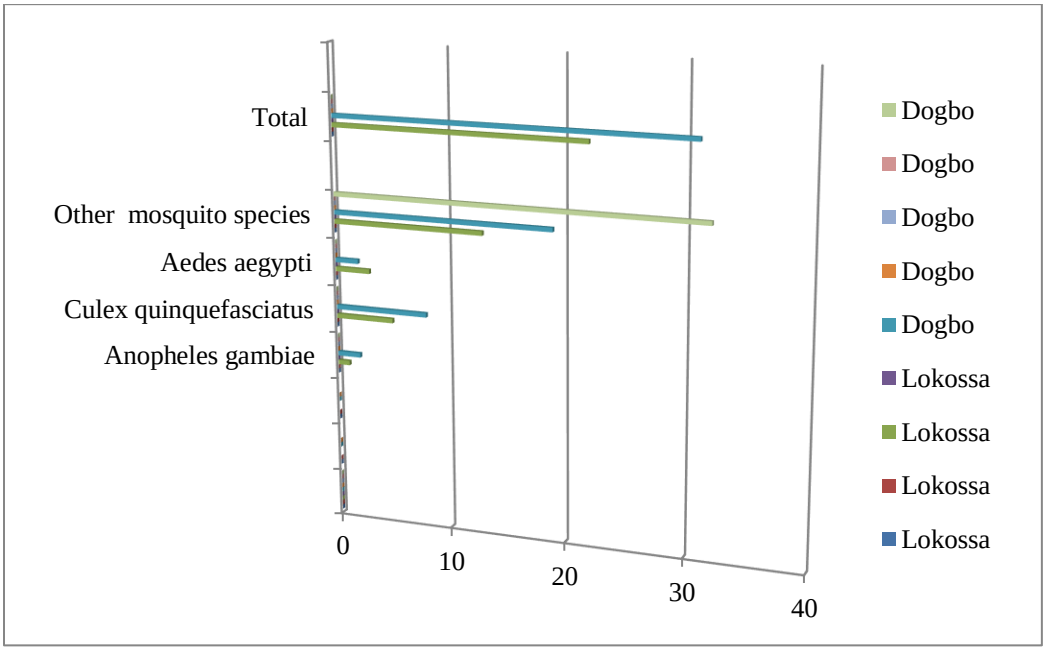

Fig. 3 Mosquito species collected in bedrooms where mosquito nets were well-appointed

The analysis of Figure 4 showed that the mosquitoes collected in bedrooms where mosquito nets were not well-appointed were higher than those collected in bedrooms where mosquito nets were well-appointed.

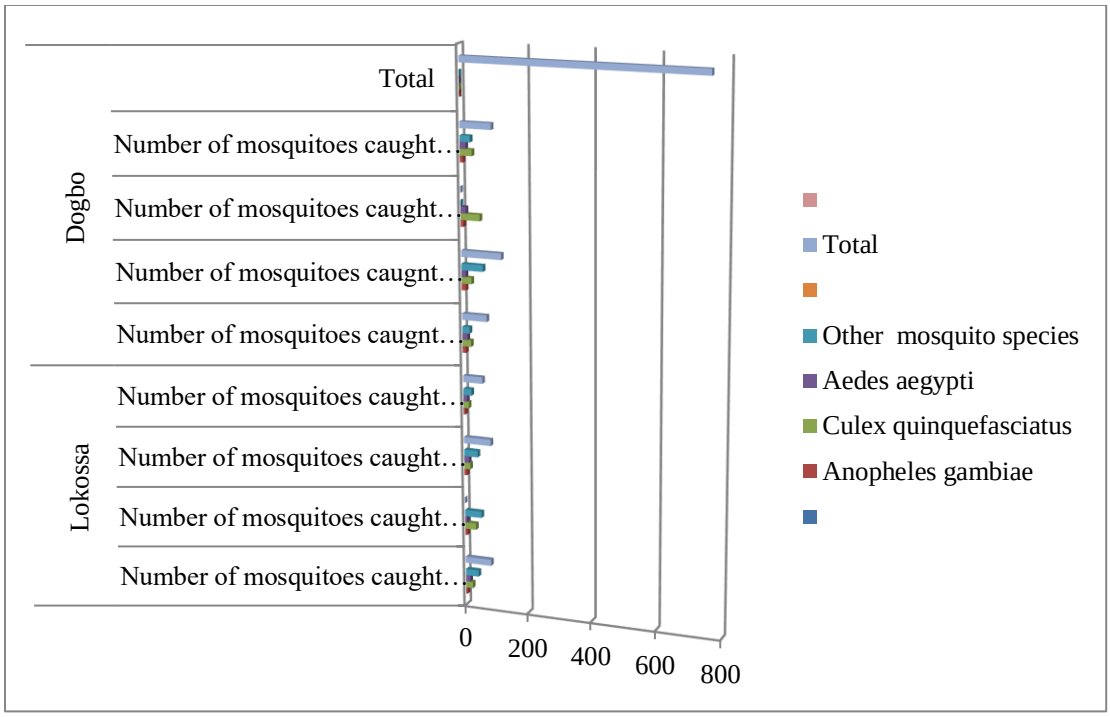

Fig. 4 Mosquito species collected in bedrooms where mosquito nets were not well-appointed

The analysis of Figure 5 showed that no gravid mosquitoes were found in the collected mosquito fauna. Only unfed and blood-fed mosquitoes were found.

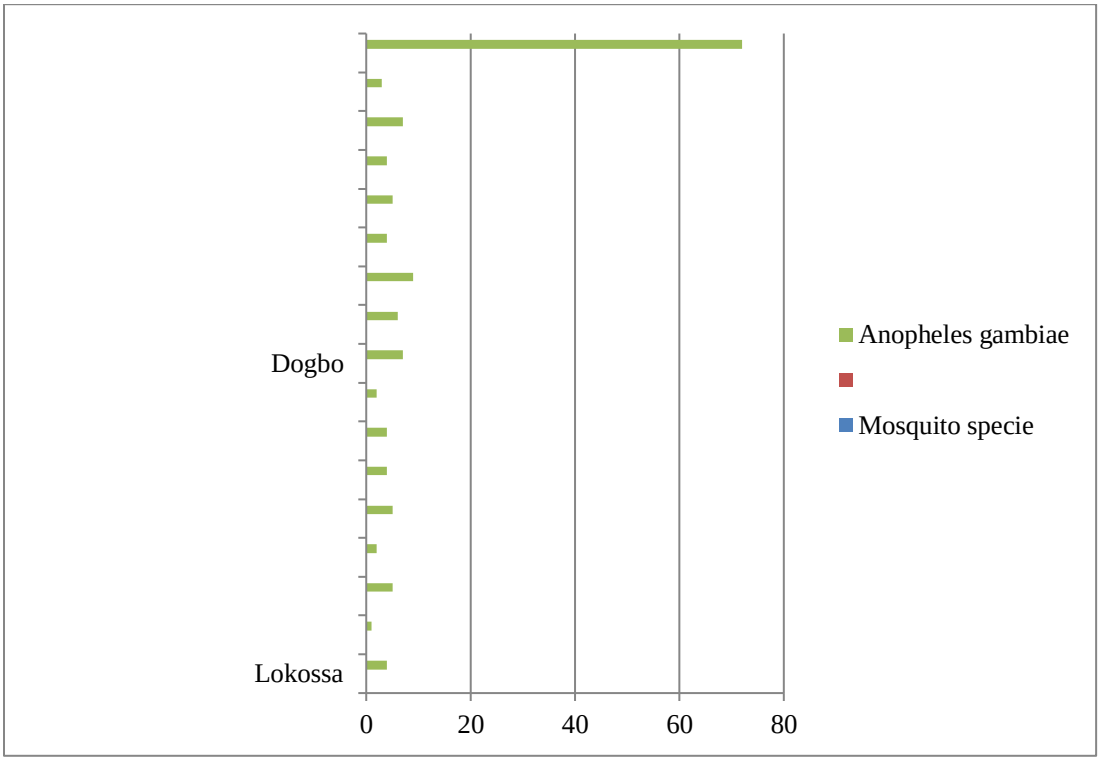

Fig. 5 Physiological status of the abdomen of collected *Anopheles gambaie* mosquitoes

The analysis of Figure 6 showed that almost all people who slept in the beds where blood-fed *Anopheles gambiae* were found were sick.

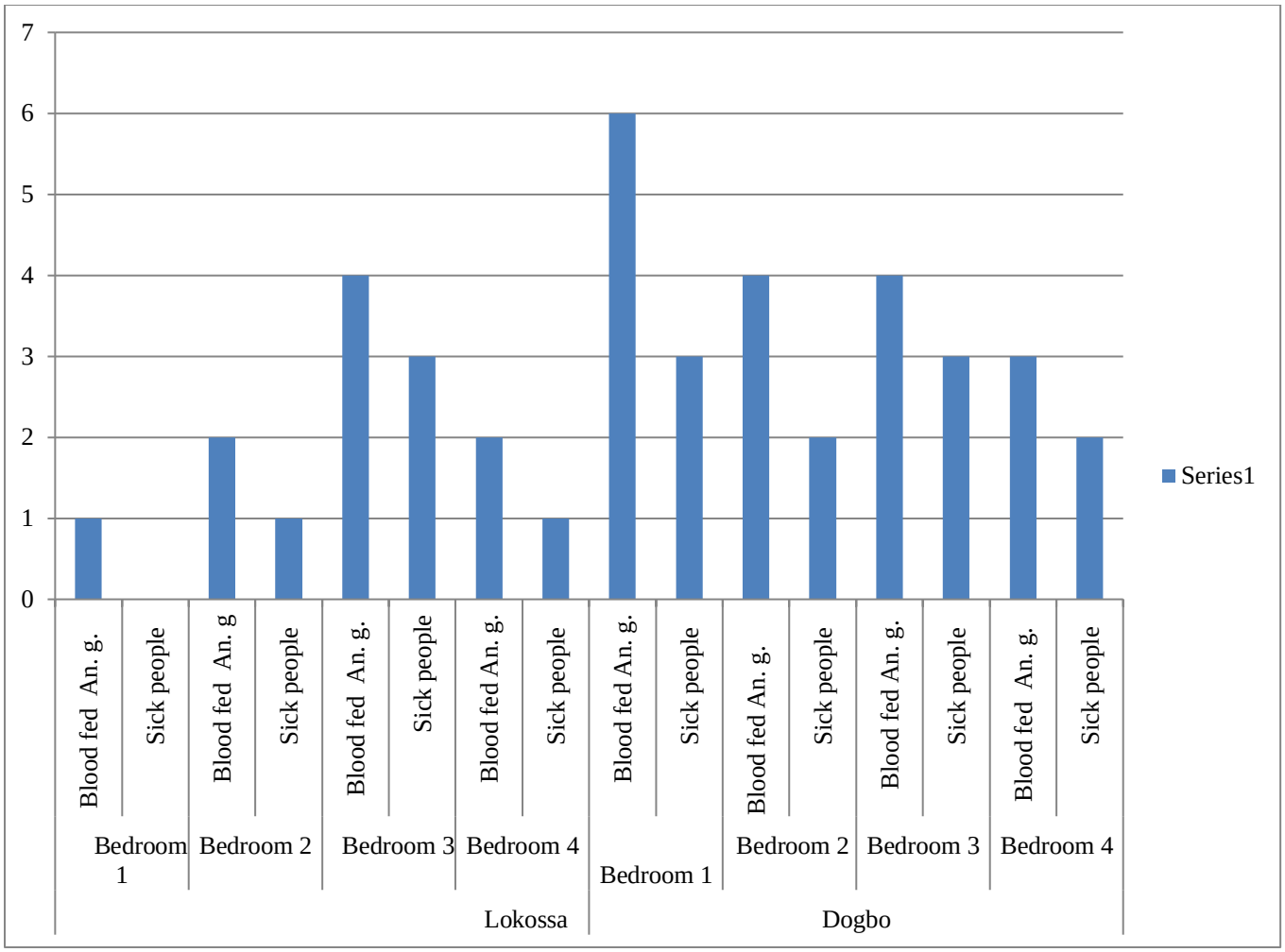

Fig. 6 Number of people with the presence of *Plasmodium falciparum* in the blood

The analysis of Table 1 showed the diagnosis of a malaria case due to *Plasmodium falciparum* in a sick person who lived in the study area.

Table 1. Diagnosis of malaria cases due to *Plasmodium falciparum* in people

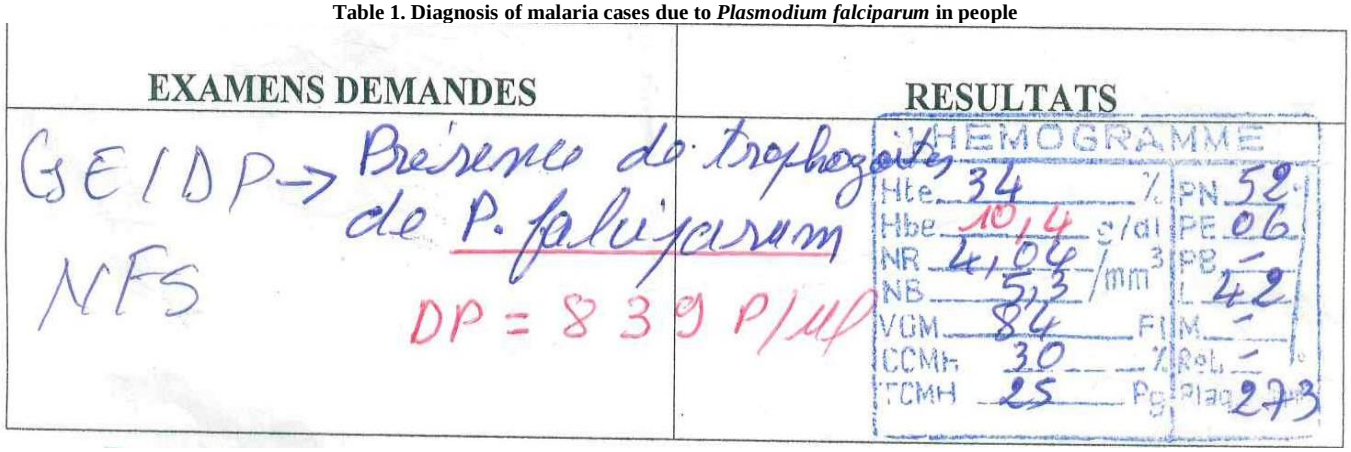

Figure 7 showed a bedroom where the mosquito net was not well-appointed in the study area, whereas Figure 8 showed a bedroom where the mosquito net was well-appointed. Regarding Figure 9, it showed the blood of killed *Anopheles gambiae* fed mosquitoes inside a bed in the study area.

Fig. 7 A bedroom where the mosquito net was not well-appointed

Fig. 8 A bedroom where the mosquito net was well-appointed

Fig. 9 The blood of killed *Anopheles gambiae*-fed mosquitoes

5. Discussion

Malaria is an important cause of illness and death in many parts of the world, especially in sub-Saharan Africa. There has been a renewed emphasis on preventive measures at the community and individual levels. The use of Long-Lasting Insecticide-treated bed Nets (LLINs) is the most prominent malaria preventive measure for large-scale deployment in highly endemic areas.

Results from experimental hut trials in Benin raise an alarm. Of key concern is whether ITNs that are subject to wear and tear under everyday household conditions fail to protect ITN users now that *An. gambiae* mosquitoes are becoming resistant. Modern mosquito nets lack physical durability, and household nets can accrue an average of 12-20 holes during 1-2 years of use. [17] Net replacement schemes struggle to meet demand at this level of deterioration and attrition.

In the current study, the mosquitoes collected in bedrooms where mosquito nets were not well-appointed were higher than those collected in bedrooms where mosquito nets were well-appointed. So, it is important to install mosquito nets well around and above the beds before sleeping at night. In addition, some mosquito species were found in bedroom 3 in the Lokossa district and bedroom 1 in the Dogbo district despite the bed nets being well-appointed. These results showed that these bed nets were torn. So, people must sleep under the mosquito bed nets, which are not torn, as the use of Long-Lasting Insecticide-treated bed Nets (LLINs) is one of the recommended measures to prevent malaria. Our results corroborated those obtained by Ntonifor and Veyufambom, who had assessed the effective use of mosquito nets in the prevention of malaria in some parts of the Mezam division, Northwest Region, Cameroon. [18] In fact, these authors had shown in their study that LLINs have significantly reduced the prevalence of malaria among the studied population, and so the government should not relent its efforts in the distribution of these nets, especially to the vulnerable groups, in order to eliminate malaria and other mosquito-borne diseases. According to these authors, the utilization of LLINs needs to be encouraged to match ownership, while free distribution of ITNs to vulnerable groups needs to be continuous and consistent.

In the current study, no *Anopheles gambiae* gravid mosquitoes were found in the collected mosquito fauna. Only unfed and blood-fed mosquitoes were found. That is good news, as *Anopheles gambiae* gravid mosquitoes will take blood meals later for the maturation of their eggs.

In the current study, almost all people who slept in the beds where blood-fed *Anopheles gambiae* were found were sick. They had received infectious bites containing the parasite responsible for the transmission of malaria disease in the country, which is *Plasmodium falciparum.* So, it is important to sleep at night on beds with mosquito nets that are not torn around and above. The necessity of communicating the importance of bed net use occurs through the National Malaria Control Program (NMCP) of Benin. Although mass distribution campaigns frequently occur, the NMCP must engage with communities more frequently to remind them why and how to use, maintain, repair, wash, and ultimately dispose of bed nets. Our results corroborated those obtained by Lengeler, who had assessed the impact of insecticide-treated bed nets or curtains on mortality, malarial illness (life-threatening and mild), malaria parasitaemia, anaemia, and spleen rates. [9] These results showed that fourteen cluster-randomized and eight individually randomized controlled trials met the inclusion criteria. Five trials measured child mortality: ITNs provided 17% Protective Efficacy (PE) compared to no nets (relative rate 0.83, 95% Confidence Interval (CI) 0.76 to 0.90), and 23% PE compared to untreated nets (relative rate 0.77, 95% CI 0.63 to 0.95). About 5.5 lives (95% CI 3.39 to 7.67) can be saved each year for every 1000 children protected with ITNs. In areas with stable malaria, ITNs reduced the incidence of uncomplicated malarial episodes in areas of stable malaria by 50% compared to no nets, and 39% compared to untreated nets; and in areas of unstable malaria: by 62% for compared to no nets and 43% compared to untreated nets for *Plasmodium falciparum* episodes, and by 52% compared to no nets and 11% compared to untreated nets for *Plasmodium vivax* episodes. When compared to no nets and in areas of stable malaria, ITNs also had an impact on severe malaria (45% PE, 95% CI 20 to 63), parasite prevalence (13% PE), high parasitaemia (29% PE), splenomegaly (30% PE), and their use improved the average haemoglobin level in children by 1.7% packed cell volume.

Mosquito nets offer physical and chemical barriers against mosquitoes that cannot enter them. When nets are torn, mosquitoes can enter them and take their blood meals. That exposes the sleepers to the risk of suffering from malaria. The physical barrier is due to the tissues used to make the nets, whereas the chemical barrier is due to the insecticides used to impregnate the mosquito nets. Two kinds of mosquito nets were often used by the people for their protection. There were: Permanet 2.0 and Olyset net. These mosquito nets were often received from the different free distributions of Long-Lasting Insecticidal Nets (LLINs) by the National Malaria Control Program (NMCP) of Benin. Some of these mosquito nets used were bought by the people or received as a donation by them. Permanet 2.0 and Olyset are impregnated with pyrethroids. According to Zaim *et al.*, pyrethroids have unique modes of action, such as fast knockdown and excito-repellent effects. [19]

Many factors must be taken into account in the prevention of malaria transmission. In fact, a study carried out by Estifanos *et al*. suggests that the risk of malaria is driven by environmental changes, along with climatic and geographic factors. [20] This follows a dynamic disease transmission process that depends on social and ecological systems, where

initial deforestation for settlements and agriculture can increase malaria risk. [21]

6. Conclusion

It is important to install mosquito nets well around and above the beds before sleeping at night. The good practice or behavior of people is important in the prevention of malaria transmission in the endemic areas of this disease.

Compliance with Ethical Standards

Acknowledgments

The authors would like to thank people from Dogbo and Lokossa districts surveyed who helped us in mosquito collection.

Statement of Ethical Approval

The study follows proper ethical procedures.

Statement of Informed Consent

Informed consent was obtained from all individual participants included in the study.

Author Contribution

The authors designed the study, supervised the study, analyzed and interpreted the data, contributed to the mapping, and drafted the manuscript.

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