SSRG International Journal of Medical Science
ISSN: 2393–9117 / https://doi.org/10.14445/23939117/IJMS-V13I3P102

Volume 13 Issue 3, 7-13, May-June 2026

Original Article

Comparison of the Effectiveness of Impregnated Torn Bed Nets and Non-Torn Untreated Bed Nets in the Prevention of Mosquito Bites in Malaria Control in Republic of Benin, West Africa

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Received: 18 April 2026 Revised: 21 May 2026 Accepted: 12 June 2026 Published: 30 June 2026

Abstract - *Background: 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 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. Objective: The current study was aimed at comparing the effectiveness of impregnated torn bed nets and non-torn untreated bed nets in the prevention of mosquito bites in malaria control. Material and methods: Eight bedrooms corresponding to eight houses were selected for adult mosquito collection in the morning in July 2025 during the great rainy season in each of two locations selected, which were Achitou and Houédjamey in Dogbo district in Couffo department. In each of these locations, four bedrooms with impregnated torn bed nets and four bedrooms with non-torn untreated bed nets were selected. Mosquitoes inside the nets were collected by electronic racket from 6 a.m. to 7 a.m in both locations. The survey was done simultaneously in both locations for fourteen 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. Results: The results showed that the non-torn untreated bed nets were most effective than impregnated torn bed nets in the prevention of human-mosquito contact. Conclusion: It is important to sleep under impregnated or treated bed nets which are not torn at night. The good practice or behavior of people is important in the prevention of malaria transmission in the endemic areas of this disease.*

Keywords *- Torn net, Human-vector contact, Malaria prevention, Republic of Benin, Mosquito Bites.*

1. Introduction

Between 2000 and 2023, an estimated 2.2 billion malaria cases and 12.7 million malaria deaths were averted worldwide, with 1.7 billion cases and 12 million deaths prevented in the WHO African Region alone. In 2023 alone, more than 177 million cases and more than 1 million deaths were averted globally. [1] In malaria-endemic countries, resistance to pyrethroids remains widespread, with resistance confirmed in 55 of the 64 countries where it was monitored between 2018 and 2023. Resistance to neonicotinoids has also been reported in five of the 16 countries where it was monitored.

Countries are encouraged to continue to test the susceptibility of mosquitoes to the insecticides used in their vector control interventions and to adopt pyrethroid-PBO or dual active ingredient ITNs to improve the effectiveness of ITNs against mosquitoes resistant to pyrethroids. [1]

The use of LLINs provides a physical barrier that reduces human-mosquito contact; furthermore, the insecticidal and repellent activity of the insecticide incorporated into the LLIN fiber protects the users as well as non-users by providing community protection through spatial effects. [2] LLINs used at the community-wide level can exhibit cumulative effects on vector density, survival and longevity over a large area and may force *Anopheles* mosquitoes to find alternative animal hosts and ultimately reduce human malaria transmission. [3] Many studies across the world have revealed that LLINs were able to reduce the malaria burden and significantly reduce the uncomplicated malarial episodes in areas of both stable and unstable malaria transmission. [2,4,5,6,7]

The bed net is the most widely used as a malaria control measure in 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 assays are conducted on these tools of prevention in order to evaluate their effectiveness. So, in addition to the evaluations of the effectiveness of LLINs used by the people by the NMCP, many assays must be conducted on these LLINs by local researchers for this purpose.

Very few researches were published on the people's practice or behavior in the prevention of malaria transmission in Benin**.** Therefore, there is a need to carry out new researches for this purpose. The goal of this study was to compare the effectiveness of impregnated torn bed nets and non-torn untreated bed nets in the prevention of mosquito bites in malaria control 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. [8] 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. [9,10] Vatandoost *et al*., had shown that in laboratory conditions, torn nets treated with pyrethroids, cyfluthrin, deltamethrin and Permethrin were effective against *Anopheles stephensi* with a high protection rate. [11]

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. [12] 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. [13] 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. [14]

3. Materials and methods

3.1. Study Area

The study area is located in the Republic of Benin (West Africa) and includes the department of Couffo. The Couffo department is located in the south-western Benin, and the study was carried out more precisely in the Dogbo district (Figure 1). The southern borders of this district are the Lokossa and Bopa districts. The northern border is the Djakotomey district. The eastern border is Lalo district, and the western border of Dogbo district is Togo republic. Dogbo district covered 475 km^2 and belongs to 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. We took these factors into account to compare the effectiveness of impregnated torn bed nets and non-torn untreated bed nets in the prevention of mosquito bites in malaria control in the Republic of Benin. Couffo has a climate with four seasons, two rainy seasons (March to July and August to November) and two dry seasons (November to March and July to August). The temperature ranges from 25 to 30°C, with the annual mean rainfall between 900 and 1100 mm.

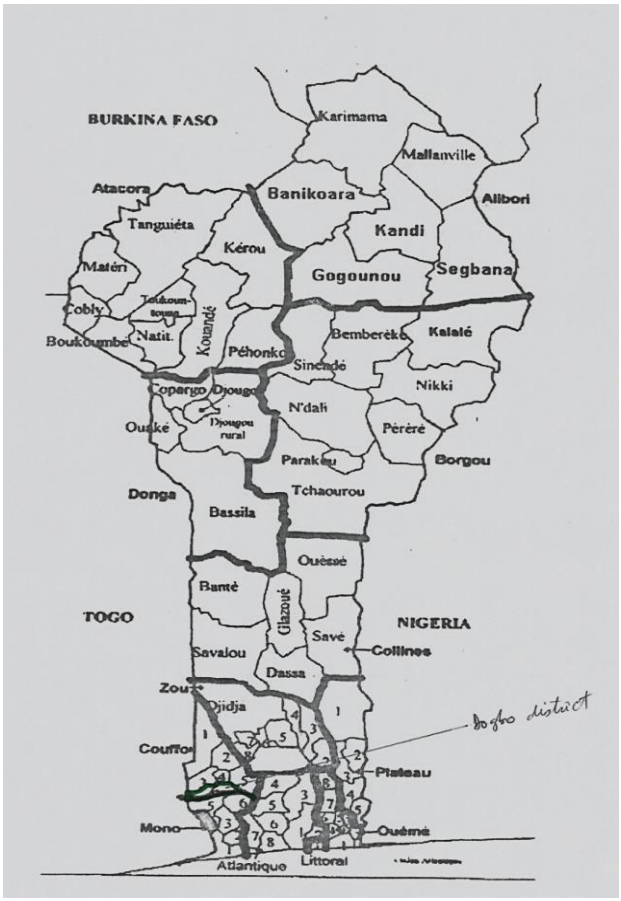

Fig. 1 Map of Republic of Benin showing Dogbo district surveyed

3.2. Field Mosquito Collection

Eight bedrooms corresponding to eight houses were selected for adult mosquito collection in the morning in July 2025 during the great rainy season in each of two locations selected, which were Achitou and Houedjamey in Dogbo district in Couffo department. In each of these locations, four bedrooms with impregnated torn bed nets and four bedrooms with no-torn untreated bed nets were selected. Mosquitoes inside the nets were collected by electronic racket (Figure 2) from 6 a.m. to 7 a.m in both locations. The survey was done simultaneously for fourteen consecutive nights (two weeks). 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.

3.3. Collected Mosquito Identification

Adult collected mosquitoes were identified to species based on morphological characters using identification keys. [15]

3.4. Statistical Analysis

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

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

4. Results and Discussion

The analysis of Figure 3 showed that a total of 1069 mosquitoes were collected under bed nets in bedrooms with impregnated torn bed nets in Dogbo district. The number of collected *Anopheles gambiae* was 80 mosquitoes in both locations surveyed. But the number of collected *Anopheles gambiae* in Achitou location was higher than that collected in Houedjamey location (χ^2=9.1; p=0.003).

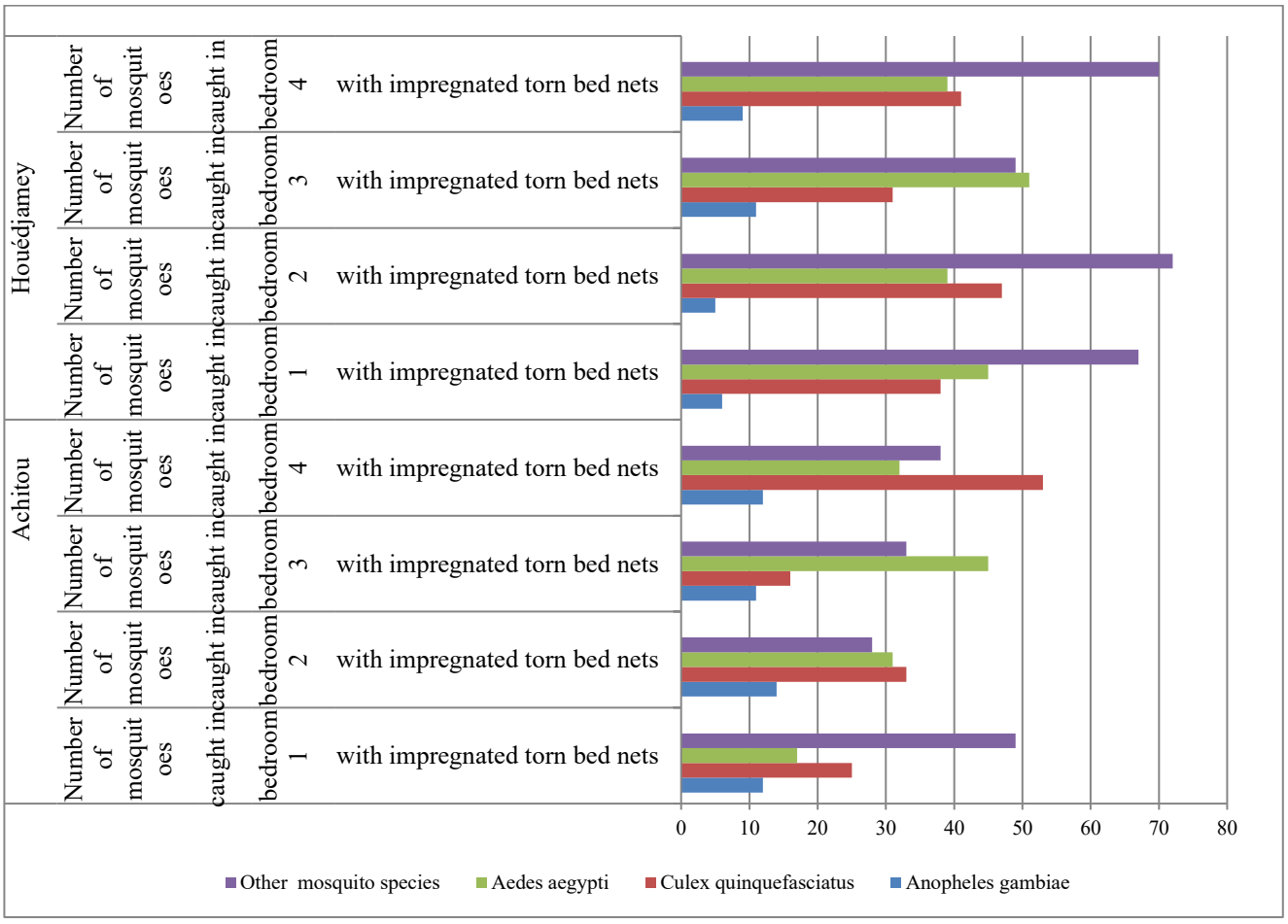

Fig. 3 Mosquito species collected in bedrooms with impregnated torn bed nets

The analysis of Figure 4 showed that a total of 662 mosquitoes were collected under bed nets in bedrooms with non-torn untreated bed nets in Dogbo district. The number of collected *Anopheles gambiae* was 50 mosquitoes in both locations surveyed. But the number of collected *Anopheles gambiae* in Achitou location was higher than that collected in Houedjamey location (χ^2=7.2; p=0.005).

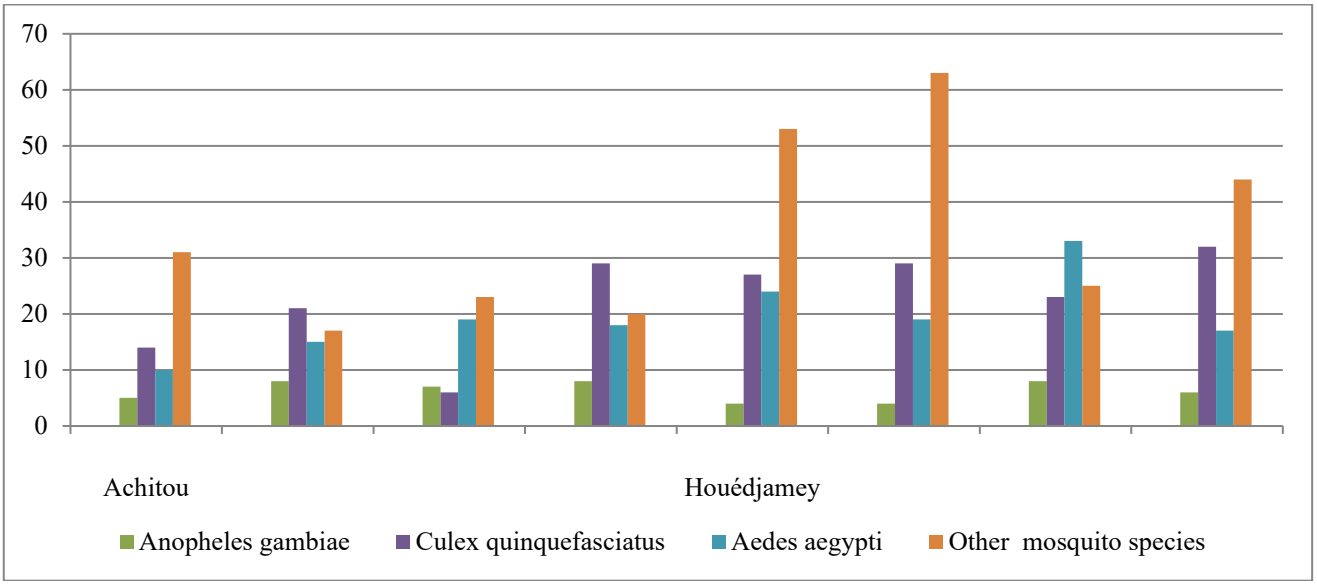

Fig. 4 Mosquito species collected in bedrooms with non-torn untreated bed nets

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. But the number of blood-fed *Anopheles gambiae* collected in Achitou location was higher than that collected in Houedjamey location (χ^2=6.5; p=0.007).

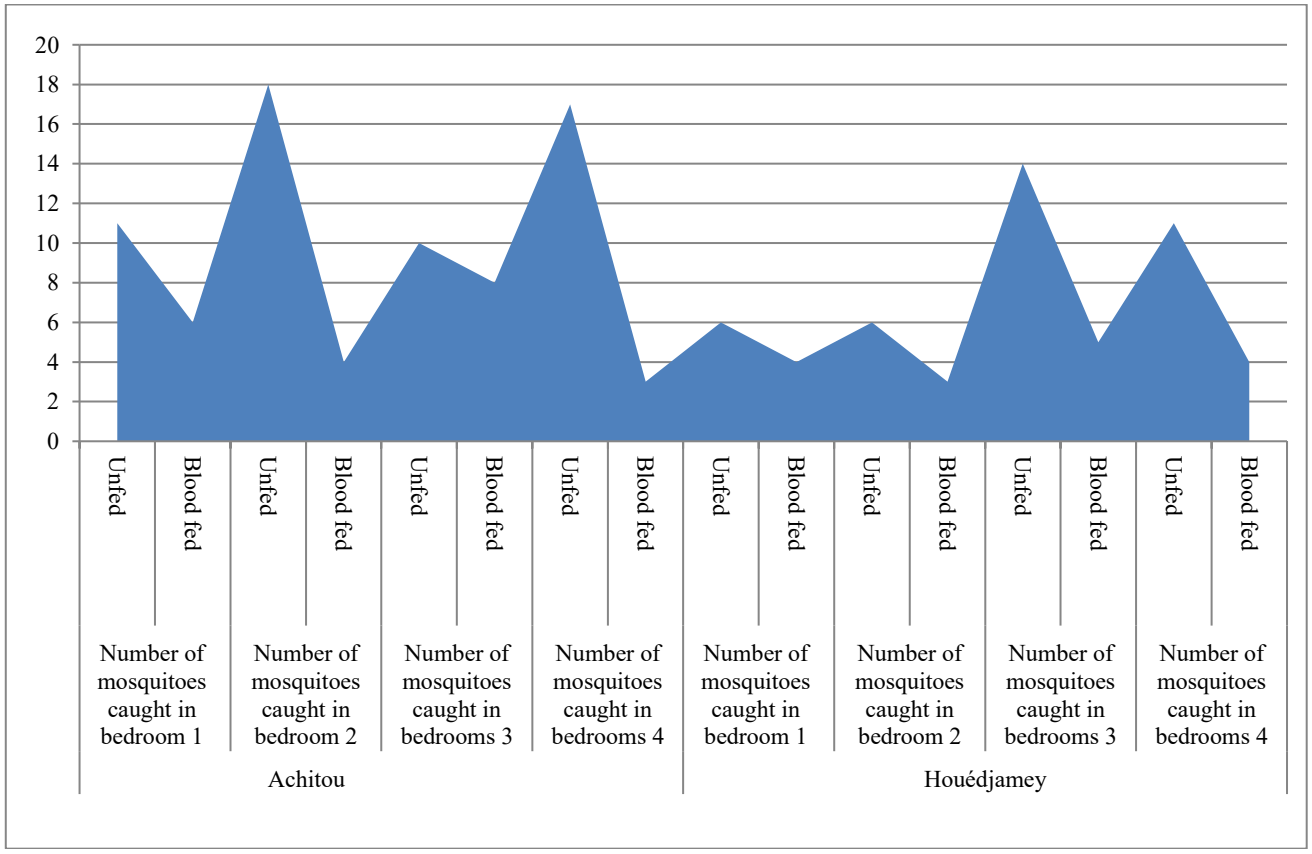

Fig. 5 Physiological status of the abdomen of collected *Anopheles gambaie* mosquitoes

Figure 6 showed a bedroom with an impregnated torn bed net, whereas Figure 7 showed a bedroom with a non-torn untreated bed net in the study area.

Fig. 6 A bedroom with an impregnated torn bed net (with holes)

Fig. 7 A bedroom with a non-torn untreated bed net (without a hole)

In the current study, the number of mosquitoes collected under bed nets in bedrooms with non-torn untreated bed nets in the Dogbo district were lower than that collected under bed nets in bedrooms with impregnated torn bed nets. These results showed that the non-torn untreated bed nets were most effective than impregnated torn bed nets in the prevention of human-mosquito contact. These results also showed that some of the non-torn untreated bed nets concerned in the current study were not well-appointed by their users before sleeping inside them. If they were well-appointed by their users, very few or no mosquito will enter inside them because of their physical barrier. Despite the insecticide contained in the torn bed nets, a lot of mosquitoes were entered inside them because after a moment of use of these bed nets, they lost their effectiveness and the insecticide product within them became no effective against mosquito repelling and killing. These results corroborated with those obtained which had studied the loss of household protection from use of insecticide-treated nets against Pyrethroid-Resistant Mosquitoes in Republic of Benin. [16] In their study, they investigated whether the nets in use were still protective. For that, they conducted household trials in northern and southern Benin, where *Anopheles gambiae* mosquitoes are susceptible and resistant, respectively, to pyrethroids. Rooms were fitted with window traps and monitored for mosquito biting and survival rates before and after the nets were treated with pyrethroid. Sleeping under an ITN in the location with resistant mosquitoes was no more protective than sleeping under an untreated net, regardless of its physical condition. By contrast, sleeping under an ITN in the location with susceptible mosquitoes decreased the odds of biting by 66%. ITNs provide little or no protection once the mosquitoes become resistant and the netting acquires holes. These authors concluded that resistance seriously threatens malaria control strategies based on ITN. Another study carried showed the evidence of man-vector contact in torn long-lasting insecticide-treated nets. [17] Their study was carried out in three geo-locations. Two types of LLINs (polyester and polyethylene) with 'standardized' physical damage were compared with similarly damaged, but non-insecticidal (control) nets. The proportionate Holes Index (pHI) of each net was 276. Mosquitoes were captured inside the nets, identified taxonomically, and subjected to molecular analysis to estimate *knockdown resistance* (*Kdr*) frequency. Their results showed that the most commonly observed species was *Anopheles gambiae,* accounting for approximately 70% (1,076/1,550) of the total mosquitoes collected both in LLINs and non-insecticidal nets. When compared with controls, the number of vectors captured in torn LLINs was significantly reduced. Nonetheless, in a night, an average of 5 *An. gambiae s.l* could enter the damaged LLINs to bite. Similar numbers of resistant mosquitoes were collected in both LLINs and non-insecticidal (control) nets. These authors concluded that at a pHI of 276, man-vector contact was observed in torn LLINs.

The insecticide at the surface of LLINs could only reduce the number of vectors. Resistant mosquitoes have the opportunity to enter both non-insecticidal (control) nets and LLINs to bite.

The necessity at communicating the importance of the use of bed nets, which are not torn, occurs by 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.

In the current study, no 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.

Mosquito nets offer physical and chemical barriers against mosquitoes that cannot enter inside them. When nets are torn, mosquitoes can enter inside them and take their blood meals. That exposes the sleepers to the risk to suffer from malaria disease. The physical barrier is due to the type of tissues (nets are made of polyester, cotton, nylon and so on…) 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 own self of 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. [18]

4.1. Novelty of the Study

Comparatively to the previous studies, the originality of the current study remains in the method used in mosquito collection. In fact, in the previous studies, they used mouth aspirators to collect mosquitoes under bed nets. However, our study is the first which used the electronic racket in mosquito collection under bed nets in the evaluation of the effectiveness of LLINs.

4.2. Study Limitations

The current study needs more duration for an appropriate mosquito collection at two sites. Otherwise, there is a small sample (eight rooms/site). The current study needs more on net classification, randomization/blinding, and confounder control (housing, net use). For that, further studies will be carried out in the future in more locations of the country by taking these factors or parameters into account.

5. Conclusion

It is important to sleep under impregnated bed nets which are not torn at night**.** The good practice or behavior of people is important in the prevention of malaria transmission in the endemic areas of this disease.

Recommendations

As some people continue to sleep at night without mosquito nets despite the efforts of the National Malaria Control Program (NMCP) of Benin for the different free distributions of Long-Lasting Insecticidal Nets (LLINs) to them, it would be pertinent to add, as tools for people protection from mosquito bites, the Indoor Residual Spraying (IRS) in each department of the country for more protection.

Conflicts of Interest

There are no conflicts of interest in regard to the publication of this paper.

Funding Statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments

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

References

[1] World Health Organization, World Malaria Report, World Health Organization, 2024. [Online]. Available: https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2024

[2] Delenasaw Yewhalaw et al., "Bio-Efficacy of Selected Long-Lasting Insecticidal Nets Against Pyrethroid Resistant *Anopheles Arabiensis* from South-Western Ethiopia," *Parasit Vectors*, vol. 5, no. 1, pp. 1-9, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[3] Caroline A. Maxwell et al., "Effect of Community-Wide use of Insecticide-Treated Nets for 3-4 Years on Malarial Morbidity in Tanzania," *Tropical Medicine and International Health*, vol. 7, no. 12, pp. 1003-1008, 2002. [CrossRef] [Google Scholar] [Publisher Link]

[4] Christian Lengeler, "Insecticide-Treated Bed Nets and Curtains for Preventing Malaria," *Cochrane Database of Systematic Reviews*, vol. 2, 2004. [CrossRef] [Google Scholar] [Publisher Link]

[5] Alexander K. Rowe et al., "The Burden of Malaria Mortality among African Children in the Year 2000," *International Journal of Epidemiology*, vol. 35, no. 3, pp. 691-704, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[6] Sibylle Gerstl et al., "Long-Lasting Insecticide-Treated Net Usage in Eastern Sierra Leone – The Success of Free Distribution," *Tropical Medicine and International Health*, vol. 15, no. 4, pp. 480-488, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[7] Hmwe Hmwe Kyu et al., "Evaluation of the Association between Long-Lasting Insecticidal Nets Mass Distribution Campaigns and Child Malaria in Nigeria," *Malaria Journal*, vol. 12, no. 1, pp. 1-8, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[8] Jenny Hill, Jo Lines, and Mark Rowland, "Insecticide-Treated Nets," *Advances in Parasitology*, vol. 61, pp.77-128, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[9] J.D. Lines, J. Myamba, and C.F. Curtis, "Experimental Hut Trials of Permethrin-Impregnated Mosquito Nets and Eave Curtains against Malaria Vectors in Tanzania," *Medical and Veterinary Entomology*, vol. 1, no. 1, pp. 37-51, 1987. [CrossRef] [Google Scholar] [Publisher Link]

[10] Stephen Masingili Magesa et al., "Trial of Pyrethroid Impregnated Bednets in an Area of Tanzania Holoendemic for Malaria, Part 2. Effects on the Malaria Vector Population," *Acta Tropica*, vol. 49, no. 2, pp. 97-108, 1991. [CrossRef] [Google Scholar] [Publisher Link]

[11] H. Vatandoost et al., "Laboratory Efficacy of Protection Rate of Torn Nets Treated with Pyrethroids, Cyfluthrin, Deltamethrin and Permethrin against *Anopheles Stephensi* (Diptera: Culicidae)," *Journal of Biological Sciences*, vol. 6, no. 2, pp. 331-336, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[12] G.R. Port, and P.F.L. Boreham, "The Effect of Bednets on Feedng by *Anopheles Gambiae* Giles (Diptera: Culicidae)," *Bulletin of Entomological Research*, vol. 72, no. 3, pp. 483-488, 1982. [CrossRef] [Google Scholar] [Publisher Link]

[13] S.R. Irish et al., "Loss of Protection with Insecticide-Treated Nets against Pyrethroid-Resistant *Culex Quinquefasciatus* Mosquitoes Once Nets Become Holed: An Experimental Hut Study," *Parasit Vectors*, vol. 1, no. 1, pp. 1-5, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[14] Andrea M. Rehman et al., "How Much Does Malaria Vector Control Quality Matter: The Epidemiological Impact of Holed Nets and Inadequate Indoor Residual Spraying," *PLoS One*, vol. 6, no. 4, pp. 1-8, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[15] Mario Coluzzi, "Morphological Divergences in the *Anopheles Gambiae* Complex," *Journal of Malariology*, vol. 43, no. 4-6, pp. 197-232, 1964. [Google Scholar]

[16] Alex Asidi et al., "Loss of Household Protection from use of Insecticide-Treated Nets Against Pyrethroid-Resistant Mosquitoes, Benin," *Emerging Infectious Diseases*, vol. 18, no. 7, pp. 1101-1106, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[17] Virgile Gnanguenon et al., "Evidence of Man-Vector Contact in Torn Long-Lasting Insecticide-Treated Nets," *BMC Public Health*, vol. 13, no. 1, pp. 1-11, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[18] M. Zaim, A. Aitio, and N. Nakashima, "Safety of Pyrethroid-Treated Mosquito Nets," *Medical and Veterinary Entomology*, vol. 14, no. 1, pp. 1-5, 2000. [CrossRef] [Google Scholar] [Publisher Link]