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Effectiveness of New-Generation Long-Lasting Insecticidal Nets in Reducing Malaria Incidence: Evidence from a Community-Based Study in Mangoum, Cameroon

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Abstract *In Cameroon, malaria remains a major public health burden, particularly in semi-rural communities such as Mangoum. Malaria incidence remains high, prompting the introduction of new-generation LLINs designed to improve vector control, overcome insecticide resistance, and enhance durability, despite widespread distribution of Long-Lasting Insecticidal Nets (LLINs). Evidence on their effectiveness in community settings is however limited. This study looked at the effectiveness of new-generation LLINs on malaria transmission in Mangoum, Foumbot. A community-based quasi-experimental design was conducted among 395 households receiving new-generation LLINs. Structured questionnaires via Kobo Collect were used to collect multistage sampling selected participants, and quantitative data on LLIN ownership, usage patterns, and malaria cases before and after distribution. Descriptive statistics and Chi-square tests in SPSS version 25 were used to analyze data, with $p < 0.05$ set as significance. Analysis showed strong associations between LLIN utilization and motivation to use nets ($\chi^2(9) = 60.079$, $p < 0.001$), net sufficiency ($\chi^2 = 27.219$, $p = 0.001$), and perceived effectiveness ($\chi^2 = 29.54$, $p < 0.001$). Households reporting more than five malaria cases decreased from 8.6% to 1.8% ($\chi^2 = 62.39$, $p < 0.001$), LLIN usage correlated with malaria reduction ($\chi^2 = 26.237$, $p < 0.001$), and longer net use was associated with fewer cases ($\chi^2 = 31.442$, $p < 0.001$), which signifies malaria incidence declined significantly after distribution. A 40.7% decline in confirmed malaria cases was confirmed by health facility records. These findings demonstrate that malaria incidence is significantly reduced at the household level by new-generation LLINs, and that the effectiveness of LLIN-based malaria control strategies in similar community settings could further be enhanced by strengthening household coverage and promoting consistent nightly use.*

Keywords *Community Uptake, Cameroon, Effectiveness, Household Utilization, Malaria Incidence, New-generation LLINs.*

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Introduction

Problem to be solved

Globally, particularly in sub-Saharan Africa, malaria remains one of the most significant public health challenges, which carries the highest burden of disease. Globally, approximately 249 million malaria cases were reported, with the African region accounting for most cases and deaths in 2022 [1]. Through bites of infected female *Anopheles* mosquitoes, malaria which is transmitted to humans is caused by protozoan parasites of the genus *Plasmodium* [2, 3].

The disease continues to cause high morbidity and mortality in endemic countries such as Cameroon despite advances in malaria control, accounting for over 40% of outpatient consultations and 30% of hospital admissions [4]. Due to environmental conditions conducive to mosquito breeding, coupled with socioeconomic barriers that limit access to preventive tools, rural communities, such as Mangoum in Foumbot Subdivision, experience high transmission [5, 6].

The effectiveness of conventional LLINs is increasingly threatened by pyrethroid resistance in Anopheles mosquito populations, although they have been widely distributed, reducing the protective efficacy of these nets and potentially reversing progress in malaria prevention [7-9]. In addition, behavioral factors, cultural beliefs, and inconsistent net usage influence the actual impact of LLINs [10, 11]. There is thus an urgent need to assess the effectiveness of new-generation LLINs in community settings where these challenges persist [5, 6].

Existing Solutions for the Problem

Globally, several malaria control strategies have been implemented to reduce transmission [12, 1].

Conventional Long-Lasting Insecticidal Nets (LLINs)

Conventional LLINs provide both physical and chemical protection against mosquitoes. Treated with pyrethroid insecticides, they repel or kill vectors and have contributed substantially to reductions in malaria incidence [13, 14].

New-Generation Long-Lasting Insecticidal Nets

To address pyrethroid resistance, new-generation LLINs have been developed:

- PBO-treated LLINs: Contain piperonyl butoxide, a synergist that inhibits mosquito detoxification enzymes, restoring pyrethroid efficacy [15, 16].
- Dual-active ingredient LLINs: Combine pyrethroids with additional chemicals, such as pyriproxyfen, disrupting mosquito reproduction and enhancing mortality [16, 17].

Indoor Residual Spraying (IRS)

Mosquitoes resting indoors after feeding, complementing LLIN coverage and reducing vector density Indoor residual spraying is targeted by Indoor Residual Spraying [15].

Chemoprevention and Other Strategies

Other interventions include:

1. Intermittent Preventive Treatment in Pregnancy (IPTp)
2. Seasonal Malaria Chemoprevention (SMC)
3. Perennial Malaria Chemoprevention (PMC)
4. Improved malaria diagnosis and treatment services.

Behavioral and Community Engagement

Community-based programs that promote awareness, education, and behavioral change improve LLIN utilization and adherence, enhancing the effectiveness of preventive interventions.

Best Existing Solution

For areas with high pyrethroid resistance, among malaria control interventions, new-generation LLINs, particularly PBO-treated nets, are the most promising. These nets inhibit mosquito detoxification enzymes, restoring pyrethroid efficacy and improving mosquito mortality [15-17].

Compared to conventional nets, field trials in Tanzania and Uganda have shown that PBO-treated LLINs significantly reduce malaria prevalence. As a result, the World Health Organization recommends their use in regions with confirmed pyrethroid resistance. These nets represent the most effective currently available solution for malaria vector control in high-resistance settings [19].

Limitations of Existing Solutions

New-generation LLINs face several limitations, despite their benefits:

- Even to new chemical combinations mosquitoes may develop resistance, compromising long-term efficacy - evolution of insecticide resistance [8, 20].
- Effectiveness is reduced by heat discomfort, improper net hanging, inconsistent use, and seasonal neglect - usage and behavioral barriers [10, 18].
- Due to logistical constraints, distribution gaps, and financial limitations remote communities may face delays - distribution and accessibility challenges [14].
- Net lifespan is reduced by frequent washing, physical damage, and poor maintenance - durability and maintenance issues [21].
- Net utilization and protective effectiveness are influenced by housing conditions, environmental factors, and cultural beliefs - contextual and socio-cultural factors [18].

Achievements of the Intervention

LLIN interventions have produced substantial global impact:

1. Between 2000 and 2019 due to preventive measures, including LLINs, malaria mortality declined significantly [12].
2. More than 1.5 billion malaria cases were prevented, and approximately 7.6 million deaths were averted worldwide [19].
3. In areas with pyrethroid resistance, new-generation LLINs have shown superior performance, thus reducing malaria transmission effectively [16, 22].

At the community level, this study contributes by:

1. Evaluating effectiveness of new-generation LLINs in Mangoum.
2. Examining community uptake and usage patterns.
3. Identifying barriers and facilitators of LLIN use.
4. Providing evidence-based recommendations for malaria prevention strategies.
5. Supporting national malaria control policies with local evidence.

Schematic Diagram / Graphical Abstract

The conceptual framework in figure 1 above shows that the effectiveness of new-generation LLINs in reducing malaria depends on several factors, including education, household size, LLIN availability, health education, cultural beliefs, access to distribution, and personal motivation. These factors influence LLIN usage (regular use, proper installation, and maintenance), which serves as the link between the determinants and the outcomes. Effective LLIN use leads to reduced malaria cases, lower treatment costs, and improved perceptions of LLINs, while age, gender, marital status, occupation, and housing type moderate these relationships. They act as moderating variables because they influence the strength or direction of the relationship between the determinants (education, household size, LLIN availability,

health education, cultural beliefs, access to distribution, and personal motivation) and effective LLIN use.

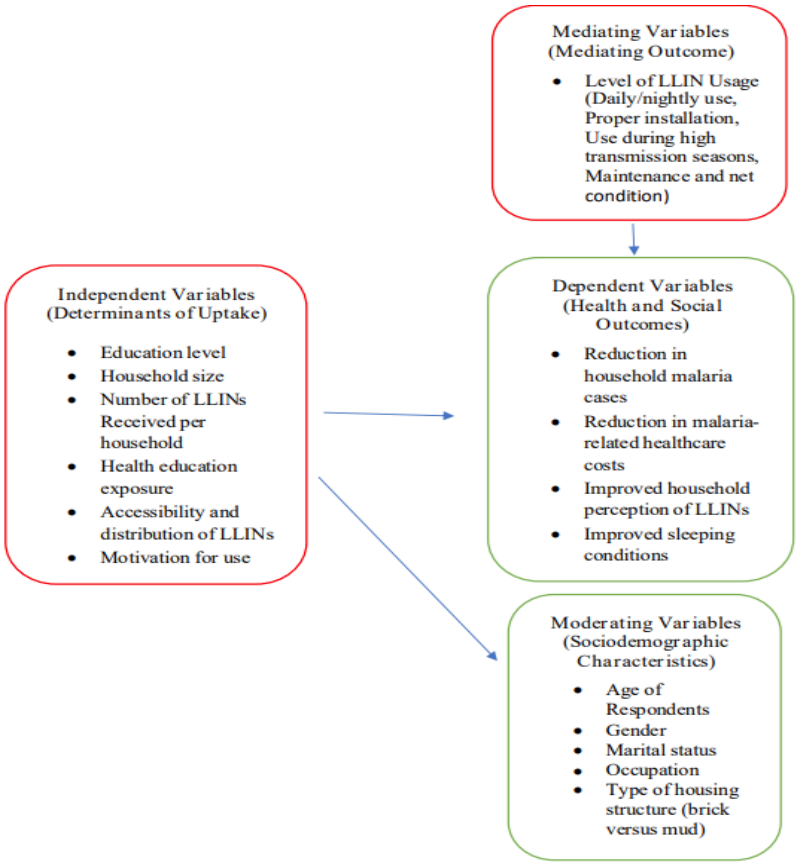

Figure 1. Conceptual Framework

Objective of the Study

General Objective:

To investigate the effectiveness of new-generation LLINs in reducing malaria transmission in Mangoum, Foumbot, Cameroon.

Specific Objectives:

To assess community uptake and utilization of new-generation LLINs in Mangoum, Foumbot, Cameroon.

To measure the impact of new generation LLINs on malaria incidence before and after net distribution.

Novelty of the work

This study is novel due to:

Context-specific evidence: Provides field-based, measurable data on malaria incidence and LLIN effectiveness in a semi-rural Cameroonian community, addressing a critical gap in epidemiological evidence.

Integration of multiple data sources: Combines survey data and health facility records to generate a comprehensive quantitative assessment of net utilization and impact on malaria transmission.

Quantitative evaluation: Employs structured household surveys to measure statistical associations between LLIN usage, household coverage, and reductions in malaria incidence.

Materials and Methods

Description of the Study Site

The study was conducted in Mangoum, a locality situated in the Foumbot Subdivision of the West Region of Cameroon, within the Noun Division. The area experiences a tropical climate characterized by two distinct seasons: a

rainy season extending from March to October and a dry season from November to February. These climatic conditions create a favorable environment for year-round mosquito breeding, which sustains persistent malaria transmission in the region.

Mangoum is predominantly rural with semi-urban pockets, representing a mixed epidemiological setting for malaria transmission. The population is largely engaged in agricultural activities, including subsistence and cash crop farming such as maize, beans, coffee, and vegetables. The community is ethnically diverse, with the Bamileke ethnic group forming the majority, alongside other groups who migrated to the area for farming and trade opportunities.

Malaria remains a major public health concern in Foumbot, ranking among the leading causes of morbidity and mortality, particularly among children under five years and pregnant women. Although the area has benefited from national LLIN distribution campaigns and malaria control programs, consistent utilization and community uptake remain variable.

Mangoum was selected as the study site due to its high malaria transmission, environmental risk factors, and recent participation in national LLIN distribution campaigns. The community has an estimated population of approximately 20,000 inhabitants, with health services mainly provided by the Mangoum Integrated Health Centre, which offers malaria diagnosis, treatment, and distribution of preventive tools such as LLINs.

The village is traditionally organized into 13 quarters or subsectors, including Mangoum Centre, Mbantou, Bamenjo, Ngangang, Fombap, Goumgoumé, Ngouet, and Nko VI. For geographic precision, the study area was georeferenced using GPS coordinates (Latitude 5.4390°N and Longitude 10.6312°E), and household locations were mapped using Google Earth to facilitate field navigation and spatial coverage during data collection.

Quantitative Investigation

The quantitative component of the study employed a community-based quasi-experimental design to assess the effectiveness of new-generation Long-Lasting Insecticidal Nets (LLINs) in reducing malaria transmission.

The study compared malaria incidence before and after the introduction of new-generation LLINs in the community. Two time periods were considered:

- Pre-intervention period: 2019-2021 (before distribution of new LLINs)
- Post-intervention period: 2022-2024 (after distribution of new LLINs)

This approach allowed the study to evaluate trends in malaria occurrence in relation to LLIN ownership and usage patterns. The intervention itself was not experimentally assigned by the researchers, as LLIN distribution was implemented through a national malaria control campaign, making the study observational but comparative in nature.

The quantitative investigation focused on several key indicators, including:

- Number of malaria cases per household before and after LLIN distribution.
- Household ownership of LLINs.
- Frequency and consistency of LLIN usage.
- Duration of net usage.
- Household perceptions of LLIN effectiveness.

Data were collected from households across selected quarters of Mangoum using a multistage sampling strategy. Initially, 9 out of the 13 quarters were purposively selected to represent geographic, social, and environmental diversity. Within each quarter, systematic random sampling was applied to select households.

The required sample size was calculated using the Cochran sample size formula, assuming a 95% confidence level, 50%

expected proportion, and a 5% margin of error. This produced a minimum sample size of 384 households, but the study ultimately surveyed 395 households to increase statistical reliability.

Description of the Laboratory Methods

Although the study was primarily community-based, health facility malaria records were used as a complementary data source to validate household-reported malaria cases. These records were obtained from the Mangoum Integrated Health Centre and nearby health posts, where malaria diagnosis is routinely conducted using standard diagnostic methods such as microscopy and rapid diagnostic tests (RDTs).

These laboratory-confirmed malaria case records provided secondary epidemiological data that allowed the researchers to compare trends in malaria incidence before and after the distribution of new-generation LLINs. The integration of health facility records strengthened the reliability of the study findings by reducing dependence solely on self-reported household data.

Description of the Statistical Methods used - Quantitative Analysis

Quantitative data collected from households were processed and analyzed using IBM SPSS Statistics version 25. Prior to analysis, survey data collected through KoboCollect were exported to Microsoft Excel for cleaning, verification, and removal of incomplete or inconsistent responses before being imported into SPSS.

The statistical analysis involved three main levels of analysis:

Univariate Analysis

Univariate analysis was used to summarize individual variables using:

- Frequencies
- Percentages
- Means
- Standard deviations

These statistics described variables such as:

- Number of LLINs received.
- Year of distribution.
- Duration of net usage.
- Perceived effectiveness of LLINs.

Likert-scale responses related to strategies for improving LLIN usage were analyzed using mean scores and standard deviations.

Bivariate Analysis

Bivariate analysis was conducted to examine relationships between pairs of variables using the Chi-square (χ^2) test of independence.

Examples of relationships tested included:

- Motivation for LLIN use and consistent net usage
- Household net sufficiency and usage consistency
- Socio-demographic variables and LLIN usage patterns
- Duration of net use and malaria incidence

The Chi-square test helped determine whether significant associations existed between these variables.

Multivariate Analysis

To further identify predictors of LLIN usage, a multiple linear regression analysis was conducted. This statistical model examined the influence of several independent variables simultaneously, including:

- Discomfort while sleeping under nets
- Lack of training on LLIN usage
- Cultural beliefs
- Lack of follow-up by health workers

The regression model assessed the direction and magnitude of influence of each variable on consistent LLIN usage while controlling for the effects of other factors.

Statistical significance was determined using a p-value threshold of 0.05.

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Results

Community Uptake and Utilization of New-Generation LLINs in Mangoum, Foumbot

The analysis of survey responses from 395 households revealed a high level of community uptake and utilization of new-generation long-lasting insecticidal nets (NG-LLINs) in Mangoum, Foumbot. Across multiple distribution years, the proportion of households reporting LLIN use remained consistently high, with more than 68% of respondents reporting net use, and nightly usage exceeding 80% in most categories (Table 1 and Figure 2). For example, 87.7% of households that received nets in 2020 and 84.5% of those receiving nets in 2022 reported using them every night. These findings indicate widespread adoption of NG-LLINs as part of routine malaria prevention practices in the community.

Table 1. Analysis of NG LLIN Usage in Relation to Household Factors

S. No	Predictor variables	NG LLIN usage	Yes, every night	Yes, occasionally	No	Others	Total	Chi-square (df)	p-value
1.	**Year Received NG LLIN**	2020	50 (87.7%)	5 (8.8%)	2 (3.5%)	0	57	$\chi^2(12) = 15.565$	.212
		2021	13 (68.4%)	3 (15.8%)	3 (15.8%)	0	19		
		2022	142 (84.5%)	15 (8.9%)	11 (6.5%)	0	168		
		2023	74 (83.1%)	10 (11.2%)	5 (5.6%)	0	89		
		2024	53 (85.5%)	8 (12.9%)	0 (0.0%)	1 (1.6%)	62		
2.	**Number of NG LLINs Received**	1	103 (77.4%)	13 (9.8%)	17 (12.8%)	0	133	$\chi^2(9) = 27.219$	.001
		2	98 (87.5%)	12 (10.7%)	2 (1.8%)	0	112		
		3	69 (87.3%)	8 (10.1%)	2 (2.5%)	0	79		
		Above 3	62 (87.3%)	8 (11.3%)	0 (0.0%)	1 (1.4%)	71		
3.	**Motivation to Use NG LLINs**	Fear of Malaria	250 (89.9%)	19 (6.8%)	9 (3.2%)	0	278	$\chi^2(9) = 60.079$	.000
		Health W. Influence	2 (66.7%)	1 (33.3%)	0 (0.0%)	0	3		
		Habit/ Tradition	8 (72.7%)	1 (9.1%)	1 (9.1%)	1 (9.1%)	11		
		Other Reasons	72 (69.9%)	20 (19.4%)	11 (10.7%)	0	103		
4.	**People Sleeping Under One NG LLIN**	1 Person	32 (72.7%)	6 (13.6%)	6 (13.6%)	0	44	$\chi^2(9) = 17.743$	.038
		2 Persons	133 (85.8%)	14 (9.0%)	7 (4.5%)	1 (0.6%)	155		

		3 Persons	129 (84.9%)	20 (13.2%)	3 (2.0%)	0	152		
		Above 3	38 (88.4%)	1 (2.3%)	4 (9.3%)	0	43		
5.	**Duration of NG LLIN Use**	Less than 6 months	15 (88.2%)	2 (11.8%)	0 (0.0%)	0	17	$\chi^2(15) = 68.519$	.000
		6–12 months	58 (85.3%)	7 (10.3%)	2 (2.9%)	1(1.5%)	68		
		1–2 years	62 (82.7%)	10 (13.3%)	3 (4.0%)	1 (1.3%)	75		
		2–3 years	108 (87.8%)	11 (9.0%)	4 (3.3%)	0	123		
		More than 3 years	85 (83.3%)	11 (10.8%)	6 (5.9%)	0	102		
		I do not know	4 (40.0%)	0 (0.0%)	6 (60.0%)	0	10		

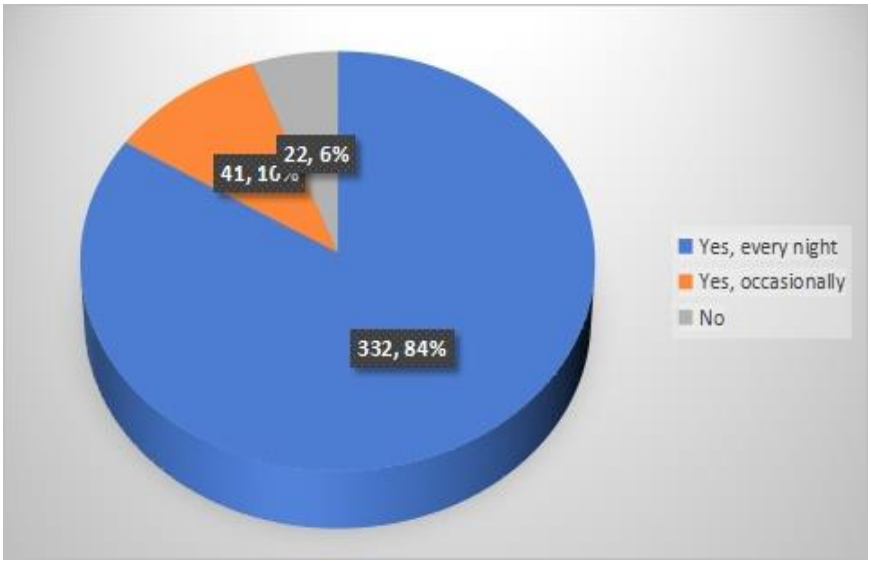

Figure 2. Current use of NG LLINs in the Household for Community Uptake

Statistical analysis demonstrated that several factors significantly influenced LLIN utilization. The number of nets received per household was strongly associated with consistent usage (χ^2, p = .001), with households receiving two or more nets reporting higher nightly usage (87.5%) compared to those receiving only one net (77.4%). Similarly, motivation to use LLINs showed a strong association with consistent use ($\chi^2(9) = 60.079$, $p < .001$). Among respondents who cited fear of malaria as their primary motivation, 89.9% reported nightly net use, compared with 69.9% among those motivated by other reasons such as comfort or routine.

Other variables significantly associated with LLIN uptake included number of people per net (p = .038), duration of net use (p = .000), frequency of washing (p = .000), method of washing (p = .000), belief that LLINs reduce malaria (p = .000), and perceived effectiveness of the nets (p = .000). In contrast, year of net distribution (p = .212) and community belief influence (p = .284) were not statistically significant predictors of utilization.

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Regression analysis further identified key determinants of consistent LLIN use (Table 2). Motivation to use LLINs (B = 0.067, SE = 0.021, p = .001) and duration of net use (B = 0.064, SE = 0.022, p = .004) were significant positive predictors of current net use. Conversely, male respondents were less likely to report regular LLIN use compared with female respondents (B = −0.116, SE = 0.054, p = .032). These findings suggest that LLIN uptake in Mangoum is influenced by a combination of behavioral motivation, household net availability, and socio-demographic characteristics, confirming that the majority of households have adopted and consistently use NG-LLINs for malaria prevention.

Table 2. Multiple Linear Regression Predicting Household use of NG LLINs

Predictor Variable	B (Unstd.)	Std. Error (SE B)	Beta (Std.) β	t	Sig. (p)	95% CI (Lower)	95% CI (Upper)
Constant	0.866	0.247	–	3.503	0.001	0.380	1.352
Gender	−0.116	0.054	−0.104	−2.155	**0.032***	−0.223	−0.010
Household size	−0.006	0.030	−0.010	−0.188	0.851	−0.065	0.054
No. of NG LLINs received	−0.047	0.025	−0.098	−1.903	0.058	−0.097	0.002
Motivation to consistently use LLINs	0.067	0.021	0.166	3.234	**0.001***	0.026	0.108
No. of people per LLIN	−0.021	0.033	−0.033	−0.640	0.522	−0.087	0.044
Duration of LLIN use	0.064	0.022	0.148	2.900	**0.004***	0.021	0.108
Main reasons preventing regular use	−0.021	0.014	−0.075	−1.496	0.136	−0.049	0.007
Assistance to repair/maintain LLIN	0.175	0.095	0.095	1.845	0.066	−0.012	0.362
Received info/training on use/maintenance	−0.071	0.033	−0.120	−2.124	**0.034***	−0.137	−0.005
Perceived contribution to malaria reduction	0.104	0.053	0.119	1.962	0.051	0.000	0.208
Change in household malaria treatment expenses	0.064	0.050	0.076	1.287	0.199	−0.034	0.163
Perceived effectiveness vs old nets	0.052	0.040	0.067	1.314	0.190	−0.026	0.130

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Impact of New-Generation LLINs on Malaria Incidence before and after Distribution

To determine the effectiveness of NG-LLINs in reducing malaria incidence, paired sample t-tests were conducted comparing malaria cases before and after net distribution among the same households.

Results showed a significant reduction in malaria incidence following the introduction of NG-LLINs. Prior to the distribution of the nets, households reported an average of 2.45 malaria cases, which declined to 1.30 cases after the introduction of NG-LLINs, representing a mean difference of 1.144 cases (Table 3). This reduction was statistically significant ($t(394) = 19.858$, $p < .001$), with a 95% confidence interval ranging from 1.031 to 1.258. The negative correlation coefficient ($r = -0.329$) indicates that households experiencing higher malaria burdens before the intervention recorded the greatest reductions following net distribution.

Table 3. Paired samples T-Test on the effectiveness of NG LLINs in reducing malaria

Comparison	Mean before NG LLIN	Mean after NG LLIN	Mean difference	95% CI of difference	t (df)	Correlation (r)	p-value
Perceived change in malaria	2.45	1.30	1.144	[1.031, 1.258]	19.858 (394)	−0.329	.000
Actual cases after (2022-2024)	2.45	1.76	0.684	[0.609, 0.758]	17.960 (394)	0.466	.000
Perceived contribution of LLINs	2.45	1.35	1.102	[0.991, 1.212]	19.582 (393)	−0.194	.000

Similarly, when comparing actual reported malaria cases before the intervention with cases reported in 2024, the average number of cases decreased from 2.45 to 1.76, resulting in a mean reduction of 0.684 cases. This difference was also statistically significant ($t(394) = 17.960$, $p < .001$) with a 95% confidence interval between 0.609 and 0.758, confirming a measurable reduction in malaria incidence after NG-LLIN distribution (Figure 3).

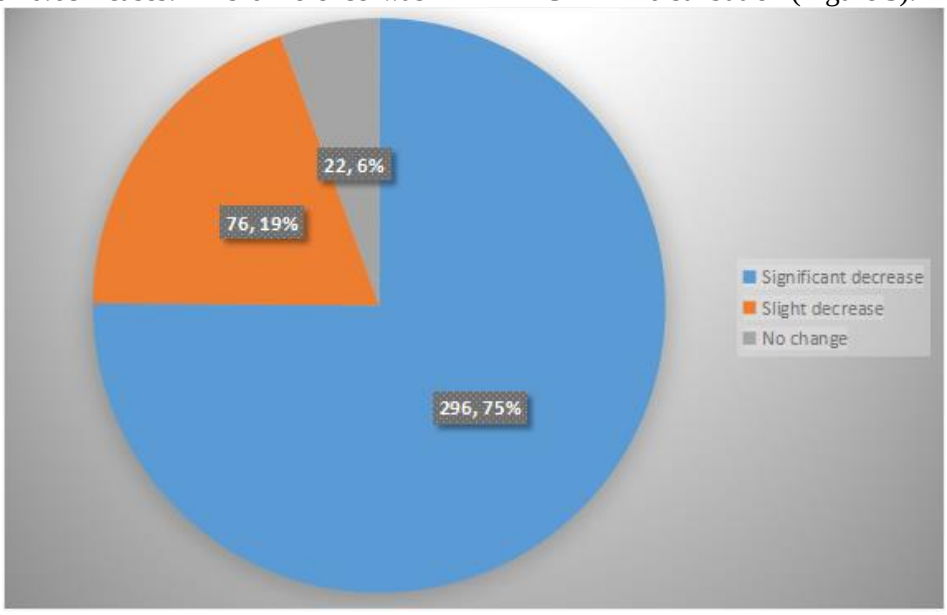

Figure 3. Change in Malaria Cases in Household Since Receiving New Generation LLINs

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Household-level analysis further illustrated this decline (Table 4; Figure 4). The proportion of households reporting no malaria cases increased from 12.9% before the intervention to 29.9% afterward, while households reporting three to five malaria cases decreased dramatically from 40.5% to 2.8%. Similarly, households reporting more than five cases declined from 8.6% to 1.8% ($p < .001$).

Table 4. Respondents Distribution on the Impact of NG LLINS on Malaria Incidence Prior to and after its Intervention

S/N	Variable	Response Option	Frequency	Percent
1.	Number of malaria cases in household before receiving NG LLINs (2019-2021)	None	51	12.9
		1–2 cases	150	38.0
		3–5 cases	160	40.5
		More than 5 cases	34	8.6
2.	Change in frequency of household malaria-related health facility visits between pre-NG LLIN (2019-2021) and post-NG LLIN (2022-2024) periods	Much less frequently	164	41.5
		Slightly less frequently	197	49.9
		About the same	33	8.4
3	Number of malaria cases in household after receiving NG LLINs (2022–2024)	None	118	29.9
		1–2 cases	259	65.6
		3–5 cases	11	2.8
		More than 5 cases	7	1.8
4.	Reduction in mosquitoes inside sleeping areas since NG LLIN usage began	Yes, a major reduction	251	63.5
		A slight reduction	99	25.1
		No reduction	40	10.1
		More mosquitoes now	5	1.3

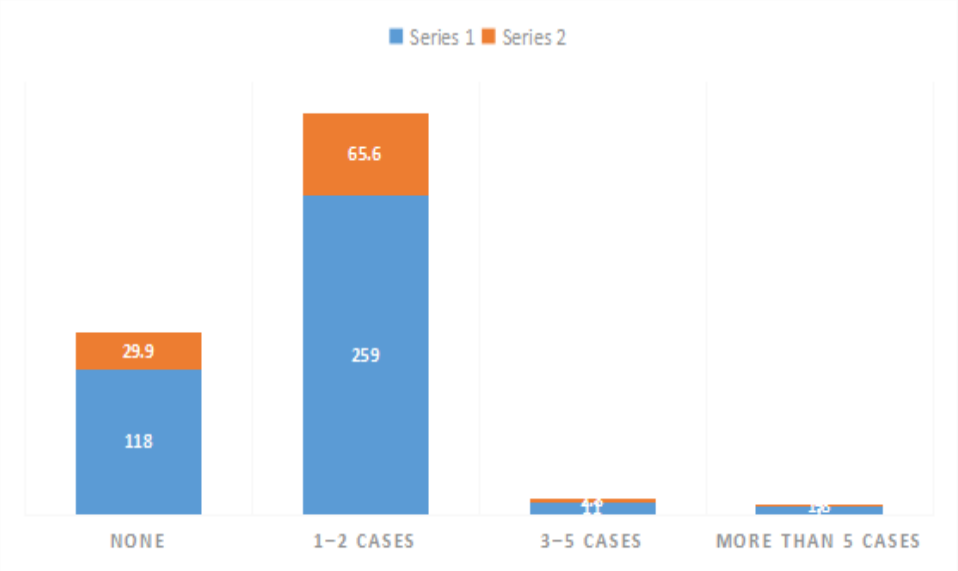

Figure 4. Number of Malaria Cases in Household after Receiving NG LLINs (2022-2024)

Additional analysis showed that longer duration of LLIN use ($p = .004$) and consistent nightly use of the nets ($p = .000$) were significantly associated with lower malaria incidence. These results were further supported by health facility records, which showed a

decline in confirmed malaria cases following the introduction of NG-LLINs, particularly in 2022 and 2023 (Figure 5).

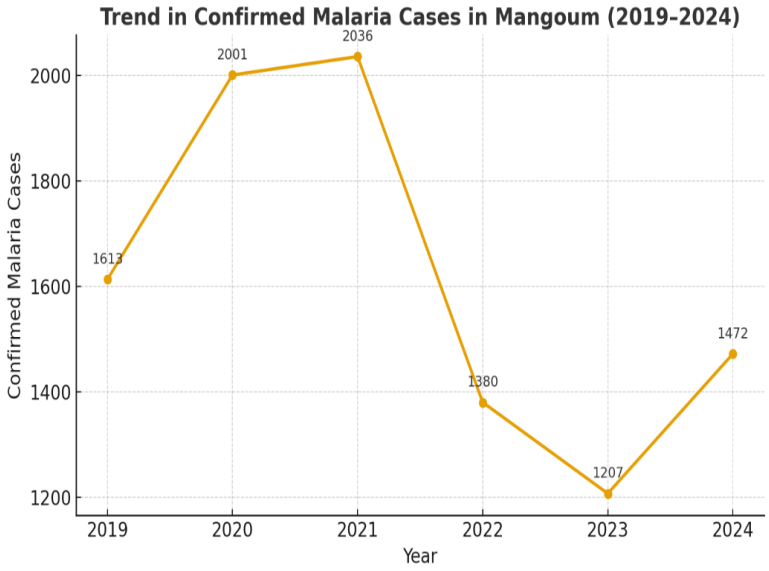

Figure 5. Trend in Confirmed Malaria cases in Mangoum (2019-2024)

Overall, the convergence of household survey data, statistical analysis, and facility records provides strong epidemiological evidence that the distribution and sustained use of new-generation LLINs significantly reduced malaria incidence in Mangoum, Foumbot.

Discussion

Community Uptake and Utilization of New-Generation LLINs

The study found that community uptake and utilization of new-generation LLINs (NG-LLINs) in Mangoum, Foumbot, was high, with over 68% of households reporting net use and nightly usage exceeding 80%. Households that received multiple nets reported higher consistent use, indicating that adequate household coverage is a key determinant of LLIN utilization. This aligns with previous research in sub-Saharan Africa, which has shown that ownership strongly predicts net use, and households with more nets are significantly more likely to use them consistently [14, 18].

Behavioral factors also played a significant role. Households reporting fear of malaria as the primary motivation had the highest nightly net use, whereas male respondents were less likely to use nets consistently. Similar findings have been reported in Tanzania and Uganda, where behavioral and motivational factors were strong predictors of LLIN use [10, 11]. Additionally, the duration of net use, number of people per net, perceived effectiveness, and correct maintenance were significantly associated with utilization, supporting earlier observations that LLIN effectiveness depends not only on distribution but also on household practices and knowledge [16, 5].

Interestingly, neither the year of net distribution nor generalized community beliefs significantly influenced utilization, suggesting that individual household practices and motivation are more critical than temporal or broad community influences. This highlights the importance of ongoing education, behavioral interventions, and follow-up programs to sustain high LLIN usage [18, 11].

Impact of New-Generation LLINs on Malaria Incidence

The introduction of NG-LLINs was associated with a significant reduction in

malaria incidence. Average malaria cases per household decreased from 2.45 before the intervention to 1.30 afterward, and households reporting no malaria cases nearly doubled from 12.9% to 29.9%, while those reporting three to five cases declined sharply from 40.5% to 2.8%. These findings are consistent with cluster-randomized trials in Tanzania and Uganda, where PBO-treated and dual-active LLINs significantly reduced malaria prevalence compared to conventional nets [15-17].

Further, longer duration of net use and consistent nightly use were significantly associated with fewer malaria cases. This corroborates evidence that correct and sustained use of LLINs is vital to achieving malaria control, particularly in areas with high pyrethroid resistance [7, 5]. Households with higher pre-intervention malaria burdens experienced the greatest reductions, supporting the idea that targeted interventions in high-risk populations maximize net effectiveness. Health facility records also reflected a decline in confirmed malaria cases, validating the household survey findings and emphasizing the actual impact of NG-LLINs [12, 4].

The results therefore provide strong epidemiological evidence that NG-LLINs significantly reduce malaria incidence in semi-rural settings, but effectiveness is moderated by behavioral, logistical, and household factors. These findings are consistent with global literature highlighting that LLINs are most effective when combined with community education, proper allocation, and behavioral reinforcement [12, 4].

Conclusion

This study provides strong epidemiological evidence that new-generation long-lasting insecticidal nets (NG-LLINs) significantly reduce malaria incidence at the household level in Mangoum, Foumbot, Cameroon. High community uptake and consistent nightly use were observed, with motivation, net sufficiency, and perceived effectiveness emerging as key determinants of utilization. Households using NG-LLINs experienced substantial reductions in malaria cases, and health facility records confirmed a 40.7% decline in confirmed malaria incidence following net distribution. These findings demonstrate that, beyond distribution, behavioral, logistical, and household factors critically influence the effectiveness of NG-LLIN-based malaria control strategies. Strengthening household coverage, promoting correct and consistent usage, and implementing targeted community education and follow-up programs could further enhance the impact of NG-LLINs. The results offer context-specific evidence to inform national malaria control policies and support the scaling up of new-generation LLIN interventions in similar semi-rural settings where pyrethroid resistance and behavioral barriers challenge malaria prevention efforts.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Ethical Approval

Ethical approval was obtained from the regional committee for ethics in human health research of the west region. Administrative authorization was obtained from the regional delegation of public health for the west region and the study areas and hospitals. Written informed consent was obtained from all participants before data collection.

Author Contributions

Frida Bessem Taku Bate epse Penda conceived and designed the study, collected the data, performed the statistical analysis, and drafted the manuscript. Innocent Mbulli Ali supervised the study, contributed to the study design, critically reviewed the manuscript, and approved the final version. Eyong Manyiyong Queenta provided technical guidance, reviewed the manuscript. All authors read and approved the final manuscript.

Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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