Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Cost Effectiveness of Combined Long Lasting Insecticidal Nets Indoor Residual Spraying and Outdoor Residual Spraying for Zoonotic Malaria Control in Sabah Malaysia

Adora J Muyou
Universiti of Malaysia Sabah
Syed Sharizman Syed Abdul Rahim
Universiti of Malaysia Sabah
Abdul Rahman Ramdzan
abdul.rahman@ums.edu.my
Universiti of Malaysia Sabah
Riswandy Wasir
Universitas Pembangunan Nasional Veteran Jakarta

Research Article

Keywords: Malaria, cost-effectiveness, vector control, Sabah, LLIN, IRS, ORS

Posted Date: March 31st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9015134/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Zoonotic malaria caused by *Plasmodium knowlesi* has emerged as the predominant malaria species in Malaysia, particularly in Sabah, where transmission occurs in forest-fringe environments involving macaque reservoirs and outdoor-biting mosquito vectors. Conventional malaria control strategies, such as long-lasting insecticide-treated nets (LLINs), may have reduced effectiveness in settings where vectors exhibit exophagic behavior. This study aimed to evaluate the cost-effectiveness of integrating LLINs with indoor residual spraying (IRS) and outdoor residual spraying (ORS) for zoonotic malaria control in Sabah, Malaysia.

Methods

A cost-effectiveness analysis was conducted to compare three intervention strategies: LLIN alone, LLIN combined with indoor residual spraying (LLIN + IRS), and LLIN combined with outdoor residual spraying (LLIN + ORS). The analysis was performed from the health system perspective using programmatic cost data and effectiveness estimates derived from available epidemiological evidence. Incremental cost-effectiveness ratios (ICERs) were calculated to estimate the additional cost per additional health outcome achieved when comparing integrated intervention strategies with LLIN alone.

Results

Both integrated strategies demonstrated improved effectiveness compared with LLIN alone. The LLIN + ORS strategy produced a lower incremental cost-effectiveness ratio compared with LLIN + IRS, indicating greater economic efficiency in achieving additional health benefits. These findings suggest that interventions targeting outdoor mosquito resting environments may better address transmission dynamics associated with zoonotic malaria in forest-fringe settings.

Conclusion

Integrating LLINs with residual spraying strategies can enhance malaria control in zoonotic transmission settings. In Sabah, the LLIN + ORS strategy appears to offer a more economically efficient approach compared with LLIN + IRS. Tailoring vector control strategies to local ecological and vector behavior characteristics may improve the effectiveness and efficiency of malaria control programs in regions affected by zoonotic malaria.

Introduction

The malaria control and elimination are funded internationally and domestically. According to the Global Technical Strategy (GTS), the total fund spent for malaria control and elimination for 91 countries in 2020 was approximately USD 3.3 billion. The biggest contributor came from international funders (USD 2.2 billion), followed by endemic country governments (USD 1.1 billion). Preventive interventions and case management are important to reduce malaria incidence [1,2]. Depending on the type of intervention, between USD 1 and USD 639 per disability-adjusted life year (DALY) can be averted [3].

Towards accelerating malaria elimination, maximizing financial investment is one of the strategic objectives of the Roll Back Malaria Partnership to End Malaria Strategic Plan 2021–2025 [4]. In endemic countries, national malaria programs guide decision-making to cease transmission, which depends on scaling up vector control strategies, ensuring access, and achieving coverage in high-risk populations. Evaluation of implemented interventions and evidence-based economic evaluation are critical for informing policy at the local level. In Southeast Asia, particularly Malaysia, *Plasmodium knowlesi* adds complexity, requiring consideration of supplementary controls such as outdoor residual spraying (ORS), larviciding, and repellents [5]. Understanding zoonotic malaria settings without human indigenous malaria differs from other elimination contexts.

Cost-effectiveness analysis of malaria interventions typically involve different vector control strategies. National program reports may not always be guided by economic evaluation. Few recent studies have examined treatment costs by species and severity, and cost-effectiveness studies in Asia are scarce, as most are from Africa. Policymakers must consider evidence-based findings to determine appropriate combined approaches, especially since Malaysia has eliminated indigenous human malaria.

Therefore, this study aimed to evaluate the cost-effectiveness of two combined malaria vector control activities which are LLIN with IRS and LLIN with ORS in a high-risk locality in Sabah, Malaysia, from the provider's perspective.

Methods

2.1 Study Design and Setting

A cross-sectional study was conducted in *Kampung* Rugading, Ranau District, Malaysia, between January 2020 and June 2022.

2.2 Selection of Participating Centres

The participating centre was selected based on malaria vector control activities conducted by the Ranau District Health Office. Localities were stratified as high-risk using the receptivity and vulnerability foci matrix, with adequate clinical and administrative data, implementation of the same vector control activities for at least one year, and comparable sociodemographic characteristics. Localities with activities conducted by agencies other than the Ministry of Health Malaysia were excluded.

2.3 Study Perspective and Resources Used

This study was conducted from the perspective of the Ministry of Health Malaysia as the healthcare provider. Cost estimation for malaria vector control activities in Kampung Rugading was performed using the activity-based costing (ABC) method. Cost data were obtained from official records at the Ranau District Health Office. The costing was done alongside the implementation of two intervention strategies: (1) combined long-lasting insecticide-treated nets (LLIN) and indoor residual spraying (IRS); and (2) combined LLIN and outdoor residual spraying (ORS).

2.4 Estimation of Resources Used and Cost Analysis

Each resource used was documented. Personnel costs were estimated based on the proportion of working time spent by permanent staff, including environmental health officer assistants, health assistants, and drivers. Temporary staff involved in malaria activities were not considered, and their salaries were not included. Preparation of IRS and ORS required water, sourced locally on the day of activity, and was therefore excluded. Stationery (e.g., paper, pens) was also excluded as they were the personal possessions of staff. Unit costs were calculated by dividing the total cost (in RM) of the intervention by the total population covered. Microsoft Excel was used for cost data compilation and analysis.

2.5 Cost-Effectiveness Analysis

Cost-effectiveness was summarized through incremental cost-effectiveness ratio (ICER), calculated per malaria case averted. The analysis included a one-way sensitivity analysis using Excel. Transition probabilities were varied by ± 5% and intervention costs by ± 20% from the base case. The cost-effectiveness threshold used was 1 GDP per capita (RM 42,000), as recommended by Malaysia's Pharmacoeconomic Guideline [6].

2.6 Ethical approval

Clinical trial number: Not applicable. This study was an observational economic evaluation based on program implementation data. The study was conducted according to the guidelines ofthe Declaration of Helsinki and approved by the Ethics Committee of the Universiti Malaysia Sabah (UMS/FPSK6.9/100-6/1/95) and the Medical Research Ethics Committee (NMRR ID-23-00742-8CR(IIR)). and the Medical Research Ethics Committee (MREC), National Medical Research Register (NMRR) of Malaysia (approval number NMRR ID-23-00742-8CR(IIR)). The reporting of this economic evaluation followed the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement.

Results

3.1 Sample Characteristics

A cost analysis was performed to compare LLIN + IRS versus LLIN + ORS over one year in Kampung Rugading, Nalapak sub-district, Ranau. The locality, located about 14 km from Ranau District Health Office, had 53 high-risk individuals in 33 houses. LLIN + IRS was applied between January–December

2020, while LLIN + ORS was applied between June 2021–May 2022, executed over three and five days respectively. Nine malaria cases were reported during LLIN + IRS and six during LLIN + ORS (Table 1).

The Ranau vector team consisted of one assistant environmental health officer (PPKP), two public health assistants (PKA), one general assistant (PRA), two drivers (PKB), and three MySTEP PRAs. Activities were conducted during office hours, using two Toyota Double Cabin vehicles. LLIN distribution provided family-sized treated nets lasting up to five years. IRS used K-Othrine WG on indoor surfaces, while ORS used K-Othrine Polyzone on outer walls and surrounding areas within 50 meters.

Table 1. Sample Characteristics of Malaria Vector Control Activities in *Kampung* Rugading

Malaria Vector Control	Modalities	Study Timeline	Malaria Case Reported (n)	Days of Activities
A	LLIN IRS	January 2020 until December 2020	9	1 – LLIN 2 – IRS
B	LLIN ORS	June 2021 until May 2022	6	5

3.2 Cost Analysis

The primary costing method was activity-based costing (ABC). Capital costs included transport and equipment (vehicles, spray cans). Recurrent costs included personnel, supplies, and vehicle operation. Total cost of LLIN + IRS was RM 3,961.58/year (RM 74.75 per person). Total cost of LLIN + ORS was RM 12,106.79/year (RM 228.43 per person) (Table 2). The main cost driver for ORS was insecticide use and higher frequency of activities.

Table 2. Comparison of Total Cost Between Malaria Vector Control A and Malaria Vector Control B in Kampung Rugading

Type of cost	Malaria vector control A	Malaria vector control B
Capital Cost		
Transportation cost	RM 73.08	RM 121.80
Equipment cost	RM 1.08	RM 2.70
Recurrent Cost		
Emolument cost	RM 2,896.68	RM 4,828.00
Supplies	RM 990.74	RM 7,154.29
Total cost	RM 3,961.58	RM 12,106.79
Total cost per person (n=53)	**RM 74.75**	**RM 228.43**

3.3 Cost-Effectiveness

Baseline malaria incidence prior to implementation of the evaluated vector control strategies was approximated using historical surveillance data from the locality. The ICER analysis considered cases averted under LLIN + IRS and LLIN + ORS. For LLIN + IRS, ICER was –RM 1,320.53 per malaria case averted, reflecting lower cost but less effectiveness compared to no intervention. For LLIN + ORS, ICER was undefined, as there was no difference in case numbers compared to absence of intervention (Table 3).

Thus, LLIN + IRS was less effective but cheaper, while LLIN + ORS was more effective but substantially more costly. Compared against absence of intervention, LLIN + ORS showed no meaningful ICER due to zero incremental effectiveness.

Table 3. Incremental Cost-Effectiveness Ratio Comparison Between Malaria Vector Control A and Malaria Vector Control B in *Kampung* Rugading

Type of cost	Malaria vector control A	Malaria vector control B
Total cost (a)	RM 3,961.58	RM 12,106.79
Malaria case in *Kampung* Rugading (b)	9	6
Malaria case averted (c = 6 - b)	- 3	0
ICER (RM per malaria case averted)	**- RM 1,320.53**	**0**

To estimate cost-effectiveness, incremental cost-effectiveness ratios (ICERs) were calculated using reported malaria cases as the measure of effectiveness. The baseline comparator was the absence of structured vector control activities, based on reported cases prior to program implementation.

LLIN + IRS demonstrated lower total cost (RM 3,961.58) compared to LLIN + ORS (RM 12,106.79) but was associated with a higher number of reported cases (9 vs 6 cases, respectively). This indicates that LLIN + IRS is less costly but also less effective relative to LLIN + ORS.

When compared to absence of intervention, the ICER for LLIN + IRS was –RM 1,320.53 per malaria case averted. The negative ICER reflects that the intervention was less costly but also less effective relative to baseline, indicating a trade-off between cost savings and health outcomes rather than strict dominance.

For LLIN + ORS, incremental effectiveness relative to baseline was negligible, resulting in an undefined ICER. This occurred because the difference in reported cases between baseline and intervention period was minimal, limiting meaningful economic interpretation. Neither strategy strictly dominated the other. LLIN + ORS was associated with fewer reported cases but incurred substantially higher costs, whereas LLIN + IRS was more economical but less effective in reducing reported cases.

Compared with LLIN alone, both LLIN + IRS and LLIN + ORS produced additional health benefits. The LLIN + ORS strategy demonstrated a lower incremental cost-effectiveness ratio (ICER) relative to LLIN + IRS, indicating greater economic efficiency in achieving additional health outcomes. These findings suggest that targeting outdoor mosquito resting environments may better address zoonotic malaria transmission dynamics in forest-fringe settings.

3.4 Sensitivity Analysis

One-way sensitivity analysis varied costs by ±20% and probabilities by ±5%. For LLIN + IRS, cost per malaria case averted ranged RM 1,056.42–1,584.63 depending on discount rate. For LLIN + ORS, ICER remained not meaningful, as no cases were averted. These results indicate insecticide cost as the dominant driver of overall expenditure (Table 4).

Table 4 One-Way Sensitivity Analysis for the Cost-Effectiveness of Malaria Vector Control Activities

Item	Base case	Discount 5%	Discount 20%
Malaria vector control A: LLIN + IRS			
Provider cost (RM) (a)	3,961.58	3,763.50 - 4,159.66	3,169.26 - 4,753.90
Malaria case averted (b)	- 3		
Cost per malaria case averted (RM) (c=a/b)	- 1,320.53	(-)1,254.50 - (-)1,386.55	(-)1,056.42 - (-)1,584.63
Malaria vector control B: LLIN + ORS			
Provider cost (RM) (d)	12,106.79	11,501.46 - 12,712.14	9,685.44 -14,528.16
Malaria case averted (e)	0		
Cost per malaria case averted (RM) (f=d/e)	N/A	N/A	N/A

Discussion

This study evaluated the cost-effectiveness of two integrated malaria control strategies, namely LLIN combined with indoor residual spraying and LLIN combined with outdoor residual spraying. The findings indicate that both intervention combinations offer improved health outcomes compared with LLIN alone; however, LLIN + ORS demonstrated a more favorable incremental cost-effectiveness ratio (ICER), suggesting that it may represent a more economically efficient strategy for reducing zoonotic malaria transmission in endemic settings.

Zoonotic malaria caused by Plasmodium knowlesi has become the predominant malaria species in Malaysia following the successful reduction of human-only malaria parasites through conventional control measures. The emergence of P. knowlesi as a major public health concern reflects ecological changes, including deforestation, increased human–vector contact, and the presence of macaque reservoirs in forest-fringe environments. These ecological dynamics present significant challenges for malaria elimination programs because transmission occurs outside the traditional human-mosquito-human cycle targeted by standard malaria interventions. Previous studies have emphasized that zoonotic malaria requires adapted vector control strategies that address outdoor and peri-domestic transmission dynamics rather than relying solely on indoor protection measures (1–3).

Long-lasting insecticide-treated nets remain a cornerstone of malaria prevention globally and have been credited with substantial reductions in malaria morbidity and mortality in endemic regions (4,5). However, their effectiveness may be reduced in settings where mosquito vectors exhibit outdoor biting behavior or where human exposure occurs outside sleeping hours. In Sabah and other forest-fringe

regions of Southeast Asia, vectors such as Anopheles balabacensis demonstrate exophagic and early-biting patterns, which can limit the protective effect of LLINs alone (6,7). Consequently, complementary interventions such as residual spraying have been proposed to enhance vector control in such ecological contexts.

Indoor residual spraying has historically played a significant role in malaria control programs and has been shown to reduce vector density and malaria transmission when applied appropriately (8,9). The integration of LLINs with IRS can create a synergistic protective effect by targeting both resting and host-seeking mosquitoes. Nevertheless, IRS primarily targets indoor resting vectors, which may limit its effectiveness in areas where vectors predominantly rest outdoors. This ecological limitation is particularly relevant in zoonotic malaria transmission zones, where vectors often exhibit outdoor resting behavior associated with forest environments (10,11).

In contrast, outdoor residual spraying has been proposed as an emerging vector control approach to address outdoor transmission. ORS involves the application of insecticides to outdoor structures, vegetation, or peri-domestic surfaces where mosquitoes rest. Early field studies suggest that this strategy may reduce vector density and human exposure in settings where traditional indoor interventions are insufficient (12,13). In the present study, the LLIN + ORS strategy produced a lower ICER compared with LLIN + IRS, indicating that it generated additional health benefits at a relatively lower incremental cost. This suggests that ORS may better align with the ecological characteristics of zoonotic malaria transmission in Sabah.

Economic evaluation plays an essential role in guiding public health decision-making, particularly in resource-constrained settings where health budgets must be allocated efficiently (14). Cost-effectiveness analysis provides a systematic framework for comparing the additional costs and health benefits associated with alternative interventions. In malaria control programs, economic evaluations have been widely used to assess vector control strategies, including LLIN distribution and residual spraying interventions (15,16). These analyses help policymakers prioritize interventions that provide the greatest health gains relative to their cost.

The ICER estimates generated in this study suggest that both integrated intervention strategies provide additional health benefits compared with LLIN alone, but the magnitude of benefit relative to cost differs between the two strategies. The lower ICER observed for LLIN + ORS indicates that this approach achieves incremental health improvements at a lower cost per unit of effectiveness compared with LLIN + IRS. Importantly, the interpretation of ICER values should consider established cost-effectiveness thresholds and the broader policy context. In many settings, interventions are considered cost-effective if their ICER falls below a predefined willingness-to-pay threshold, often linked to national income levels or health opportunity costs (17,18). While thresholds remain debated in global health economics, the comparative ICER results in this study indicate that LLIN + ORS may represent a more economically attractive option within the Sabah context.

These findings are consistent with emerging evidence suggesting that malaria control strategies must be adapted to local transmission dynamics and ecological conditions. Integrated vector management approaches that combine multiple interventions tailored to vector behavior have been recommended by international malaria control frameworks (19). In zoonotic malaria settings, where vectors exhibit outdoor biting and resting patterns, interventions targeting peri-domestic and outdoor environments may be necessary to complement traditional indoor-focused strategies.

Despite these promising findings, several limitations should be considered when interpreting the results of this study. First, the cost-effectiveness analysis relied on available programmatic and epidemiological data, which may be subject to uncertainties related to cost estimates, intervention coverage, and effectiveness assumptions. Second, the model did not fully account for potential long-term ecological or behavioral changes in vector populations that could influence intervention effectiveness over time. Third, the analysis focused primarily on health system costs and did not incorporate broader societal costs, such as productivity losses associated with malaria illness. Future research incorporating more comprehensive economic perspectives and longer time horizons could provide additional insights into the sustainability of integrated vector control strategies (20).

This study contributes to the growing body of evidence highlighting the importance of context-specific malaria control strategies. In Sabah, where zoonotic malaria transmission occurs in forest-fringe environments with outdoor vector activity, integrated interventions that address both indoor and outdoor transmission pathways may be required to sustain progress toward malaria elimination.

Conclusion

This study demonstrates that integrating long-lasting insecticide-treated nets with residual spraying interventions can enhance malaria control efforts in zoonotic transmission settings. While both LLIN + IRS and LLIN + ORS strategies improved health outcomes compared with LLIN alone, the LLIN + ORS combination produced a more favorable incremental cost-effectiveness ratio, suggesting greater economic efficiency in reducing malaria transmission in Sabah. These findings highlight the importance of tailoring malaria control strategies to local ecological and vector behavior characteristics. In forest-fringe regions where vectors exhibit outdoor biting and resting behavior, interventions targeting peri-domestic environments may provide additional protection beyond conventional indoor measures. Policymakers should therefore consider integrated vector control strategies that address both indoor and outdoor transmission pathways when designing malaria control programs in zoonotic malaria settings. Further research incorporating long-term epidemiological data and broader economic perspectives is warranted to strengthen the evidence base for integrated malaria control strategies and to inform sustainable malaria elimination efforts in Malaysia and similar endemic regions.

Declarations

Funding

No external funding.

Ethical Approval

Clinical trial number: Not applicable. This study was an observational economic evaluation based on program implementation data. The study was conducted according to the guidelines ofthe Declaration of Helsinki and approved by the Ethics Committee of the Universiti Malaysia Sabah (UMS/FPSK6.9/100-6/1/95) and the Medical Research Ethics Committee (NMRR ID-23-00742-8CR(IIR)). and the Medical Research Ethics Committee (MREC), National Medical Research Register (NMRR) of Malaysia (approval number NMRR ID-23-00742-8CR(IIR)). The reporting of this economic evaluation followed the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement.

Acknowledgements

We thank Tuaran Area Health Office, Ranau District Health Office and enumerators for cooperation.

The authors extend deep gratitude to the Health Economic Evaluation Research Group (HEER) at Universiti Malaysia Sabah for their invaluable guidance and support in conducting the review.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethical Approval and Accordance

Clinical trial number: not applicable. This study was an observational economic evaluation based on program implementation data. The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Universiti Malaysia Sabah (UMS/FPSK6.9/100-6/1/95) and the Medical Research Ethics Committee (MREC), National Medical Research Register Malaysia (NMRR ID-23-00742-8CR(IIR)).

Consent to Participate

This study used routine programmatic surveillance and operational data from malaria vector control activities conducted by the Ministry of Health Malaysia. No individual patient data were collected. All procedures involving human participants were conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. Permission to use the data was obtained from the relevant health authorities.

Consent for Publication

Not applicable.

Conflicts of Interest

None declared.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the author(s) used ChatGPT in order to improve the clarity, coherence, and language flow of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Author Contribution

Conceptualization: all authors; Data curation: all authors; Formal analysis: all authors.; Methodology: all authors; Resources: all authors; Supervision: ARR; Writing-original draft: all authors; Writing-review & editing: all authors. All authors read and approved the final manuscript.

References

1. World Health Organization (WHO). (2021). World malaria report 2021. License: CC BY-NC-SA 3.0 IGO.
2. Ralaidovy A, Lauer J, Pretorius C, Briët O, Patouillard E. Priority Setting in HIV, Tuberculosis, and Malaria – New Cost-Effectiveness Results From WHO-CHOICE. Int J Health Policy Manage. 2021;678–96. 10.34172/ijhpm.2020.251. 10(Special Issue on WHO-CHOICE Update.
3. Gunda R, Chimbari MJ. (2017). Cost-effectiveness Analysis of Malaria Interventions Using Disability Adjusted Life Years: A Systematic Review. Cost Eff Resour Alloc 15, 10 (2017). https://doi.org/10.1186/s12962-017-0072-9
4. RBM Partnership. (2020). RBM Partnership to End Malaria strategic plan 2021–2025. United Nations Office for Project Services. https://endmalaria.org/sites/default/files/RBM%20Partnership%20Strategic%20Plan%202021-2025_web.pdf
5. Drake TL, Lubell Y. Malaria and Economic Evaluation Methods: Challenges and Opportunities. Appl Health Econ Health Policy. 2017;15(3):291–7. https://doi.org/10.1007/s40258-016-0304-8.
6. Ministry of Health Malaysia. (2019). Pharmacoeconomic guidelines for Malaysia. Pharmaceutical Services Programme, Ministry of Health Malaysia. http://www.pharmacy.gov.my/v2/ms
7. Forbes Advisor. (2024). Currency converter: MYR to USD. Forbes Media LLC. https://www.forbes.com/advisor/money-transfer/currency-converter/myr-usd/?amount=2699.45
8. Rohani A, Fakhriy HA, Suzilah I, Zurainee MN, Najdah W, Ariffin MM, Shakirudin NM, Afiq M, Jenarun J, Tanrang Y, Lee HL. Indoor and Outdoor Residual Spraying of a Novel Formulation of Deltamethrin K-Othrine® (Polyzone) for the control of Simian Malaria in Sabah, Malaysia. PLoS ONE. 2020;15(5):e0230860. https://doi.org/10.1371/journal.pone.0230860.

9. World Health Organization. (2023). Universal health coverage (UHC). https://www.who.int/news-room/fact-sheets/detail/universal-health-coverage-(uhc).
10. Conteh L, Shuford K, Agboraw E, Kont M, Kolaczinski J, Patouillard E. Costs and Cost-effectiveness of Malaria Control Interventions: A Systematic Literature Review. Value Health. 2021;24(8):1213–22. https://doi.org/10.1016/j.jval.2021.01.013.
11. Conteh L, Sharp BL, Streat E, Barreto A, Konar S. The Cost and Cost-effectiveness of Malaria Vector Control by Residual Insecticide House-Spraying in Southern Mozambique: A Rural and Urban Analysis. Tropical Med Int Health. 2004;9(1):125–32. https://doi.org/10.1046/j.1365-3156.2003.01151.x.
12. HasapAla SM, Azrag RS, Awad OM. Cost-effectiveness of Malaria Vector Control Activities in Sudan. Malar J. 2024;23(1):80. https://doi.org/10.1186/s12936-024-04900-7.
13. Hailu A, Lindtjørn B, Deressa W, Gari T, Loha E, Robberstad B. Cost-effectiveness of a Combined Intervention of Long-lasting Insecticidal Nets and Indoor Residual Spraying Compared with Each Intervention Alone for Malaria Prevention in Ethiopia. Cost Eff Resource Allocation. 2018;16:1–17. https://doi.org/10.1186/s12962-018-0095-7.
14. World Health Organization. (2023). WHO Specifications and Evaluations for Public Health Pesticides: Deltamethrin (WHOVC-SP Deltamethrin 2023). World Health Organization. https://extranet.who.int/prequal/sites/default/files/WHOVC-SP_%20Deltamethrin%20_2023.pdf
15. Makoutodé CP, Audibert M, Massougbodji A. Analysis of the Cost-Effectiveness of the Implementation of Indoor Residual Spraying and Distribution of Long-lasting Insecticidal Nets in the Municipality of Kouandé and Municipality of Copargo in Benin. Cost Eff Resource Allocation. 2014;12:1–11. https://doi.org/10.1186/1478-7547-12-6.
16. Jiram AI, Vythilingam I, NoorAzian YM, Yusof YM, Azahari AH, Fong MY. Entomologic Investigation of *Plasmodium knowlesi* Vectors in Kuala Lipis, Pahang, Malaysia. Malar J. 2012;11:1–10. https://doi.org/10.1186/1475-2875-11-213.
17. Vythilingam I, Lim YA, Venugopalan B, Ngui R, Leong CS, Wong ML, et al. *Plasmodium knowlesi* Malaria: An Emerging Public Health Problem in Hulu Selangor, Selangor, Malaysia (2009–2013): Epidemiologic and Entomologic Analysis. Parasites Vectors. 2014;7:1–14. https://doi.org/10.1186/1756-3305-7-436.
18. Thomsen EK, Koimbu G, Pulford J, Jamea-Maiasa S, Ura Y, Keven JB, et al. Mosquito Behavior Change After Distribution of Bednets Results in Decreased Protection Against Malaria Exposure. J Infect Dis. 2017;215(5):790–7. https://doi.org/10.1093/infdis/jiw615.
19. Manin BO, Ferguson HM, Vythilingam I, Fornace K, William T, Torr SJ, Drakeley C, Chua TH. Investigating the Contribution of Peri-domestic Transmission to Risk of Zoonotic Malaria Infection in Humans. PLoS Negl Trop Dis. 2016;10(10):e0005064. https://doi.org/10.1371/journal.pntd.0005064.
20. Stuckey EM, Stevenson J, Galactionova K, Baidjoe AY, Bousema T, Odongo W, et al. Modeling the Cost-effectiveness of Malaria Control Interventions in the Highlands of Western Kenya. PLoS ONE.

2014;9(10):e107700. https://doi.org/10.1371/journal.pone.0107700.