



Mosquito Shield-Transfluthrin Spatial Repellents Against Malaria-Transmitting Anopheles: A Systematic Review and Meta-Analysis

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Abstract

Background: Malaria remains a major mosquito-borne disease in tropical and subtropical regions. Although insecticide-treated nets and indoor residual spraying have contributed to malaria control, residual transmission and pyrethroid resistance require complementary vector control strategies. Mosquito Shield™ is a transfluthrin-based passive spatial repellent designed to reduce human–*Anopheles* contact. This systematic review and meta-analysis aimed to evaluate the effectiveness of Mosquito Shield in reducing exposure to malaria-transmitting *Anopheles* mosquitoes.

Methods: A systematic literature search was conducted in November 2024 using Medline/PubMed, Scopus, ScienceDirect, and Cochrane for studies published between 2019 and 2024. Eligible studies were randomized or cluster-randomized controlled trials conducted in malaria-endemic or epidemic-prone areas that evaluated transfluthrin-based Mosquito Shield compared with placebo. Outcomes included Human Landing Catch, incidence rate ratio or risk ratio, and protective efficacy. Risk of bias was assessed using RoB 2.0, and meta-analysis was performed using Review Manager 5.4.1 with a random-effects model.

Discussion: Two studies met the inclusion criteria. Mosquito Shield reduced *Anopheles* landing rates compared with placebo, with protective efficacy ranging from 34.2% to 70%. The pooled risk ratio was 0.45 (95% CI: 0.21–0.98; $p = 0.04$), indicating a significant reduction in mosquito exposure. However, heterogeneity was high ($I^2 = 95\%$).

Conclusion: Mosquito Shield™ may reduce exposure to malaria-transmitting *Anopheles* mosquitoes, but evidence remains limited by the small number of studies and substantial heterogeneity.

Keywords: *Anopheles*, malaria, meta-analysis, spatial repellent, transfluthrin

Background

Malaria and other mosquito-borne diseases remain major global health problems, particularly in tropical and subtropical areas where environmental conditions support mosquito breeding and parasite transmission. Malaria control has relied heavily on vector control strategies, especially insecticide-treated nets and indoor residual spraying. Despite important achievements, these methods do not fully prevent outdoor, early evening, or residual transmission, and their effectiveness may be compromised by insecticide resistance.^{1–8}

Spatial repellents have been developed as complementary vector control tools to reduce human-

vector contact. These products release volatile active ingredients into the surrounding air, creating a treated space that disrupts mosquito host-seeking behavior, landing, or feeding. Transfluthrin is a volatile pyrethroid used in passive emanator devices, including Mosquito Shield, and has been evaluated as an intervention that may provide protection without electricity, combustion, or direct skin application.^{9–12}

Evidence on transfluthrin-based spatial repellents is growing, but reported effectiveness may vary across mosquito species, geographic regions, ecological conditions, and local resistance patterns. A systematic review and meta-analysis is therefore needed to synthesize available evidence regarding the effect of



Mosquito Shield™ on Anopheles landing rates and protective efficacy. This review aimed to evaluate the effectiveness of Mosquito Shield in reducing human exposure to malaria-transmitting Anopheles mosquitoes.^{13,14}

Methods

Study Design and Reporting Guideline

This study was designed as a systematic review and meta-analysis and was conducted in accordance with the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline.

Eligibility Criteria

Studies were included if they met the following criteria: randomized controlled trials or cluster-randomized controlled trials; published between 2019 and 2024; conducted in malaria-endemic or epidemic-prone areas; evaluated Mosquito Shield or transfluthrin-based passive spatial repellent products; used placebo or control comparators; and reported outcomes related to human exposure to Anopheles mosquito bites, Human Landing Catch (HLC), incidence rate ratio (IRR), risk ratio (RR), or protective efficacy (PE).

Studies were excluded if they evaluated non-transfluthrin repellents, lacked full-text availability, were conducted in non-endemic malaria areas or low mosquito exposure settings, did not report relevant entomological or protective efficacy outcomes, or were reviews, editorials, commentaries, and other non-original studies.

Search Strategy

A comprehensive literature search was conducted in November 2024 across Medline/PubMed, Scopus, ScienceDirect, and Cochrane. The search used the following terms and Medical Subject Headings where applicable: “Spatial Repellent,” “Transfluthrin,” “Anopheles,” “Malaria,” and “Mosquito Shield.” Reference lists of eligible studies were also reviewed using a snowball approach to identify additional relevant articles.

Study Selection and Data Extraction

Two independent reviewers (DP and AH) screened titles and abstracts to exclude irrelevant records. Potentially eligible articles were assessed through full-text review. Disagreements were resolved through discussion. Two reviewers (AH and HZ) independently extracted data from included full-text

articles using a predefined Microsoft Excel form. Extracted variables included author and year of publication, study location, sampling method, study design, vector species, intervention, comparator, HLC, IRR or RR, PE, and statistical significance. Final verification was performed by an additional reviewer (DP).

Risk of Bias Assessment and Statistical Analysis

Three independent reviewers (DP, AH, and HZ) assessed the quality of included studies using the Risk of Bias 2.0 (RoB 2.0) tool. Meta-analysis was performed using Review Manager (RevMan) version 5.4.1. The pooled effect estimate was calculated using a random-effects model. Effect size was expressed as risk ratio with 95% confidence intervals. Statistical significance was set at $p < 0.05$. Heterogeneity was assessed using the I^2 statistic. Publication bias was evaluated using a funnel plot; however, interpretation was limited because only two studies were included.

Results

Study Selection

A total of 405 records were identified through database searches: PubMed ($n = 379$), Scopus ($n = 20$), and Cochrane ($n = 6$). After removal of 377 duplicate records (194 manually and 183 automatically), 28 records remained for screening. Sixteen records were excluded after title and abstract screening, leaving 12 reports sought for retrieval. Seven reports could not be retrieved. Of five reports assessed for eligibility, three were excluded. Ultimately, two studies were included in the systematic review and meta-analysis.

Characteristics of Included Studies

Two single-blind randomized controlled trials were included: Swai et al.¹³, conducted in semi-field huts in Tanzania, and Fongnikin et al.¹⁴, conducted in a malaria-endemic village in Benin. Swai et al. evaluated Anopheles arabiensis over 32 nights, while Fongnikin et al. evaluated Anopheles gambiae s.l. over 32 days. Both studies compared Mosquito Shield with placebo and reported outcomes related to mosquito landing reduction and protective efficacy.

Effectiveness of Mosquito Shield™

Swai et al.¹³ reported lower HLC in the Mosquito Shield™ group than in the placebo group (5.591 vs. 16.392), corresponding to an IRR/RR of 0.30 and a protective efficacy of 70% ($p < 0.001$). Fongnikin et al.¹⁴ reported lower HLC in the Mosquito Shield™ group compared with placebo (3.862 vs. 5.376),

corresponding to an IRR/RR of 0.658 and a protective efficacy of 34.2% ($p < 0.001$).

The pooled analysis using a random-effects model showed that Mosquito Shield™ significantly reduced mosquito exposure compared with placebo (pooled RR = 0.45, 95% CI: 0.21-0.98; $p = 0.04$). Heterogeneity was high ($I^2 = 95\%$), indicating substantial between-study variability. Funnel plot interpretation was limited due to the small number of included studies.

Discussion

This systematic review and meta-analysis found that Mosquito Shield, a transfluthrin-based passive spatial repellent, significantly reduced Anopheles mosquito landings compared with placebo. The pooled estimate indicated a 55% relative reduction in mosquito exposure, although the confidence interval was wide and the number of included studies was small. These findings support the potential role of Mosquito Shield as a complementary vector control tool in malaria-endemic settings.^{13,14}

The magnitude of effect differed between the two included studies. Swai et al.¹³ reported greater protective efficacy against Anopheles arabiensis in Tanzania, whereas Fongnikin et al.¹⁴ reported a more modest but still significant effect against Anopheles gambiae s.l. in Benin. Differences in vector species, pyrethroid resistance profiles, mosquito behavior, population density, housing or hut conditions, temperature, humidity, and local ecological context may have contributed to the high heterogeneity observed in the meta-analysis.

The findings are relevant for malaria vector control because spatial repellents may fill protection gaps not fully addressed by insecticide-treated nets and indoor residual spraying. Passive transfluthrin-based devices may be useful in settings where human-vector contact occurs outside sleeping hours or in semi-open environments. However, implementation should be guided by local entomological surveillance, resistance monitoring, and assessment of community acceptability.

This review has several limitations. Only two studies were eligible for quantitative synthesis, which limits the precision of the pooled estimate and restricts the ability to conduct subgroup, sensitivity, or publication

bias analyses. The high heterogeneity also indicates that the pooled effect should be interpreted cautiously. Further large-scale randomized and cluster-randomized trials across diverse ecological regions are needed to confirm effectiveness, evaluate durability, and determine optimal deployment strategies.^{13,14}

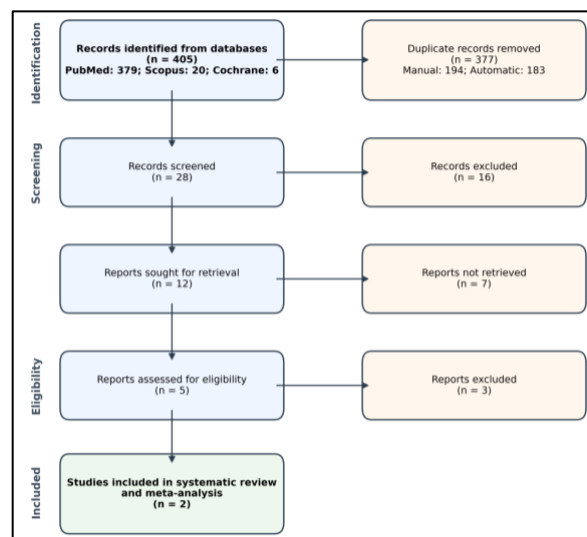


Figure 1. PRISMA Flow Diagram

Study	Randomization	Deviations	Missing data	Outcome measurement	Selective reporting	Overall
Fongnikin et al., 2024	+	+	+	+	+	+
Swai et al., 2023	+	+	+	+	+	+

Figure 2. Risk of Bias Summary

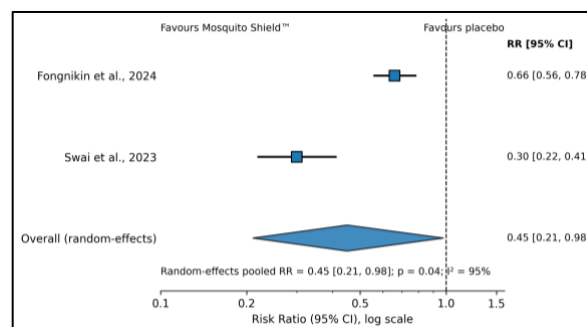


Figure 3. Forest plot showing the effect of Mosquito Shield compared with placebo in reducing Anopheles mosquito landing rates

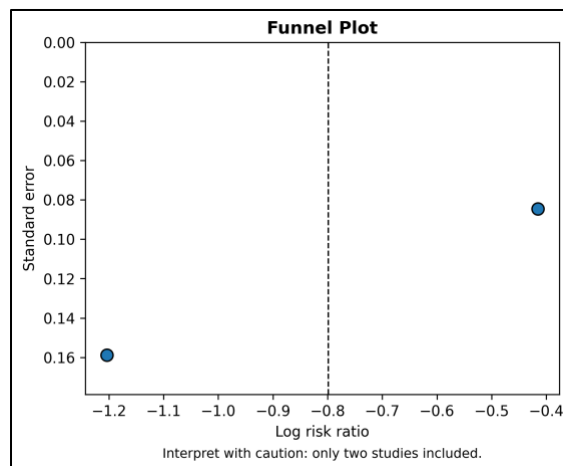


Figure 4. Funnel plot assessing potential publication bias among the included studies.

Table 1. Characteristics of included studies.

Authors, Year	Study Design	Location and Data Collection	Population	Vector	Results
Swai et al., 2023	Single-blind randomized controlled trial	Tanzania; semi-field huts; 32 nights	16 huts for landing catches; 8 huts for blood-feeding measurement	Anopheles arabiensis	Mosquito Shield™ significantly reduced HLC with an IRR of 0.3, indicating a protective efficacy of 70% in reducing mosquito landings compared with placebo ($p < 0.001$).
Fongnikin et al., 2024	Single-blind randomized controlled trial	Benin; malaria-endemic village; 32 days	15 households per arm	Anopheles gambiae s.l.	Mosquito Shield™ achieved an IRR of 0.658, with a protective efficacy of 34.2% in reducing mosquito landings compared with placebo ($p < 0.001$).

Table 2. Effectiveness of Mosquito Shield in reducing Anopheles landing rates

Study	HLC Mosquito Shield™	HLC Placebo	IRR/RR	Protective Efficacy (%)	p-value
Swai et al., 2023	5.591	16.392	0.30	70	<0.001
Fongnikin et al., 2024	3.862	5.376	0.658	34.2	<0.001

Table 3. Summary of pooled meta-analysis findings.

Outcome	Number of Studies	Effect Measure	Pooled Effect	Heterogeneity
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Anopheles mosquito landing reduction	2	Risk ratio, random-effects model	RR 0.45 (95% CI: 0.21-0.98); p = 0.04	I ² = 95%
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Conclusion

Mosquito Shield transfluthrin spatial repellent demonstrated a statistically significant protective effect in reducing human exposure to malaria-transmitting Anopheles mosquitoes. The pooled analysis suggested meaningful reduction in mosquito landing rates; however, the evidence remains limited by the small number of included studies and high heterogeneity. Further large-scale studies across diverse malaria-endemic settings are required before broad implementation recommendations can be established.

Acknowledgments

None.

Author Contributions

All authors act as the guarantor of the manuscript. DPN is the main investigator of this study. DPN, DARD, and PP contributed to conceptualization, study design, supervision, and critical revision. DPN and AHA conducted the literature search, screening, and study selection. AHA and HZFF performed data extraction and data curation. DPN, AHA, and HZFF assessed the risk of bias. FA contributed to statistical analysis and interpretation of the meta-analysis. ARR contributed to manuscript drafting, reference management, and preparation of tables and figures. All authors reviewed and approved the final manuscript.

Conflict of Interests

None.

Funding

None.

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