Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 2335-2344 | ISSN:2251-6727

Effectiveness of Vector Control Approaches in Mitigating Dengue Epidemics: A Systematic Review and Meta-Analysis

Shiny Vincent[1*], Harbans Singh Bava[2]

[1]Department of Medical Laboratory, Leonard Hospital, Tamil Nadu, India

[2] Senior Consultant, Department of Paediatrics, Krishna Institute of Medical Sciences, Krishna Vishwa Vidyapeeth Deemed University, Karad, Satara

Corresponding Author: Shiny Vincent

(Received: 16 August 2025 Revised: 20 September 2025 Accepted: 04 October 2025)

KEYWORDS

Dengue, Vector Control, Aedes aegypti, Integrated Vector Management, Systematic Review, Meta-Analysis, Wolbachia, Source Reduction

ABSTRACT:

Background: Dengue remains one of the most significant mosquito-borne viral diseases worldwide, imposing a major public health and economic burden in tropical and subtropical regions. In the absence of universally effective vaccines or antivirals, vector control remains the cornerstone of dengue prevention. However, evidence on the comparative effectiveness of various control interventions remains fragmented.

Methods: A systematic review and meta-analysis were conducted following PRISMA 2020 guidelines. Electronic databases (PubMed, Scopus, Web of Science, and Cochrane Library) were searched for studies published between January 2000 and June 2025. Eligible studies included randomized controlled trials, quasi-experimental, and observational studies evaluating vector control interventions—chemical, biological, environmental, or integrated approaches—with dengue incidence or entomological indices as outcomes. Data were pooled using a random-effects model, and heterogeneity was assessed using the I^2 statistic.

Results: Of 4,256 identified records, 68 studies from 24 countries met inclusion criteria. Pooled analysis demonstrated that Integrated Vector Management (IVM) reduced dengue incidence by 42% (RR = 0.58; 95% CI: 0.46-0.74) compared with no intervention. Larval source reduction combined with community participation achieved a 37% risk reduction (RR = 0.63; 95% CI: 0.49-0.81), while chemical control alone showed modest short-term impact (RR = 0.78; 95% CI: 0.62-0.98). Biological controls, including Bacillus thuringiensis israelensis (Bti) and Wolbachia-infected mosquitoes, achieved a 51% reduction in the Breteau Index (95% CI: 41-61%). Publication bias was minimal, and sensitivity analyses confirmed the robustness of findings.

Conclusion: Integrated, community-based, and biologically oriented vector control interventions demonstrate the highest and most sustainable impact on dengue prevention. Reliance on chemical control alone is inadequate for long-term reduction of transmission. National dengue programs should adopt Integrated Vector Management aligned with WHO's Global Vector Control Response (GVCR) 2017-2030, emphasizing intersectoral collaboration, community engagement, and resistance management to achieve sustained control of dengue epidemics.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 2335-2344 | ISSN:2251-6727

Introduction

Dengue fever is one of the most rapidly spreading mosquito-borne viral diseases worldwide and continues to pose a major global health challenge, particularly in tropical and subtropical regions [1]. The disease is caused by four antigenically distinct serotypes of the dengue virus (DENV-1 to DENV-4), belonging to the *Flaviviridae* family and primarily transmitted by *Aedes aegypti* and *Aedes albopictus* mosquitoes [2,3]. The World Health Organization (WHO) estimates that approximately 390 million dengue infections occur annually, of which about 96 million manifest clinically with varying severity ranging from dengue fever to severe dengue and dengue hemorrhagic fever [4]. Over the past two decades, the global incidence of dengue has increased more than eightfold, fueled by rapid urbanization, inadequate vector control, increased human mobility, and climate variability [5,6].

The public health impact of dengue is profound, with recurrent epidemics imposing substantial economic and healthcare burdens on endemic countries [7]. In many regions, particularly in Southeast Asia and Latin America, dengue outbreaks overwhelm healthcare systems during seasonal peaks, resulting in high morbidity, loss of productivity, and substantial costs associated with hospitalization and outbreak response [8]. Despite ongoing efforts to develop vaccines and antiviral treatments, preventive measures remain the cornerstone of dengue control due to the limited efficacy and coverage of the currently available vaccine, Dengvaxia, and the absence of specific antiviral therapies [9,10]. Consequently, vector control remains the primary and most effective strategy to interrupt dengue transmission.

Vector control strategies aim to reduce the population density, lifespan, and human-vector contact of *Aedes* mosquitoes through chemical, biological, environmental, and integrated approaches [11]. Traditional measures such as space spraying (fogging) and indoor residual spraying (IRS) using insecticides have been widely implemented, but their effectiveness is often limited by operational constraints, short-lived effects, and the growing problem of insecticide resistance among *Aedes* populations [12,13]. Furthermore, uncoordinated and reactive implementation of chemical control during outbreaks tends to yield only temporary reductions in mosquito density without sustained impact on transmission [14].

In contrast, source reduction strategies targeting larval habitats, including elimination of breeding sites, environmental sanitation, and improved solid waste management, have shown potential for long-term vector control, especially when combined with community participation and health education [15,16]. Biological control methods such as the use of *Bacillus thuringiensis israelensis* (Bti), larvivorous fish, and *Wolbachia*-infected mosquitoes represent promising alternatives, offering environmentally sustainable and potentially self-sustaining mechanisms for reducing dengue transmission [17-19]. Integrated Vector Management (IVM), advocated by WHO, incorporates a combination of these approaches, emphasizing evidence-based decision-making, intersectoral collaboration, and community involvement [20].

However, the effectiveness of these vector control interventions varies widely across regions and implementation contexts. Differences in ecological conditions, socio-behavioral factors, and operational capacity influence outcomes, making it difficult to generalize findings or identify the most effective strategies [21,22]. Moreover, while several systematic reviews have evaluated specific interventions, such as insecticide-treated materials or community-based campaigns, a comprehensive meta-analysis comparing multiple vector control approaches and quantifying their relative effectiveness in reducing dengue incidence and entomological indices remains limited [23-25].

Therefore, this systematic review and meta-analysis aim to synthesize existing evidence on the effectiveness of diverse vector control strategies-chemical, biological, environmental, and integrated-in mitigating dengue epidemics. By quantitatively assessing their impact on dengue incidence and vector indices, this review seeks to inform evidence-based policymaking and optimize dengue prevention programs in endemic regions.

Methods

This systematic review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [26]. The study protocol was

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 2335-2344 | ISSN:2251-6727

designed a priori to ensure methodological rigor and transparency.

A comprehensive literature search was performed in PubMed, Scopus, Web of Science, and the Cochrane Library to identify relevant articles published between January 2000 and June 2025. The search strategy combined controlled vocabulary and free-text terms related to *"dengue," "Aedes aegypti," "vector control," "insecticide," "source reduction," "biological control,"* and *"integrated vector management."* Boolean operators "AND" and "OR" were applied to combine terms appropriately. Reference lists of included studies and relevant reviews were also hand-searched to identify additional eligible studies [27].

Studies were included if they evaluated one or more vector control interventions aimed at preventing or reducing dengue transmission and reported measurable outcomes in terms of dengue incidence, serologically confirmed cases, or entomological indices such as the Breteau Index (BI), House Index (HI), or Container Index (CI). Eligible designs comprised randomized controlled trials (RCTs), quasi-experimental studies, and observational studies (cohort or controlled before-after). Articles were excluded if they were purely modeling studies, lacked control or comparator groups, or focused exclusively on non-dengue arboviruses [28].

Two independent reviewers screened all titles and abstracts, followed by full-text assessment to determine eligibility. Discrepancies between reviewers were resolved by consensus or, when necessary, through adjudication by a third senior reviewer. Data extraction was performed independently using a standardized data collection form that captured study characteristics (author, year, country, design, duration), type of intervention (chemical, biological, environmental, or integrated), target vector species, outcome indicators, and quantitative results. When multiple effect estimates were presented, the most adjusted estimate controlling for confounders was extracted [29].

The methodological quality of included studies was critically appraised. For RCTs, the Cochrane Risk of Bias Tool was employed, assessing random sequence generation, allocation concealment, blinding, completeness of outcome data, and selective reporting [30]. For non-randomized studies, the ROBINS-I (Risk of Bias in Non-randomized Studies - of Interventions) tool was used to evaluate potential confounding, selection bias, misclassification, and reporting bias [31]. Each study was categorized as having low, moderate, or high risk of bias.

Quantitative synthesis was conducted using random-effects meta-analysis (DerSimonian and Laird method) to account for expected heterogeneity across diverse settings and study designs [32]. Relative risks (RRs) with corresponding 95% confidence intervals (CIs) were used as the common measure of effect for dichotomous outcomes, while standardized mean differences (SMDs) were used for continuous entomological indices. When necessary, data were log-transformed to approximate normal distribution. Statistical heterogeneity was evaluated using the I^2 statistic, with values of 25%, 50%, and 75% representing low, moderate, and high heterogeneity, respectively [33]. Potential publication bias was examined visually using funnel plots and statistically using Egger's regression test [34].

Subgroup analyses were conducted to explore sources of heterogeneity, stratifying by type of intervention (chemical vs. biological vs. environmental vs. integrated), geographical region, and study design. Sensitivity analyses were performed by sequentially omitting individual studies to assess the robustness of pooled estimates. All statistical analyses were carried out using Review Manager (RevMan) version 5.4 and STATA version 17.0 software.

Ethical approval was not required for this study, as it utilized secondary data extracted from previously published articles.

Results

Study Selection

The initial database search retrieved 4,256 records, of which 3,782 remained after removing duplicates. Following title and abstract screening, 421 full-text articles were assessed for eligibility. After applying inclusion and exclusion criteria, 68 studies were finally included in the qualitative synthesis, and 52 studies contributed quantitative data to the meta-analysis (Figure 1). The PRISMA flow diagram summarizing the selection process is provided in Figure 1.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 2335-2344 | ISSN:2251-6727

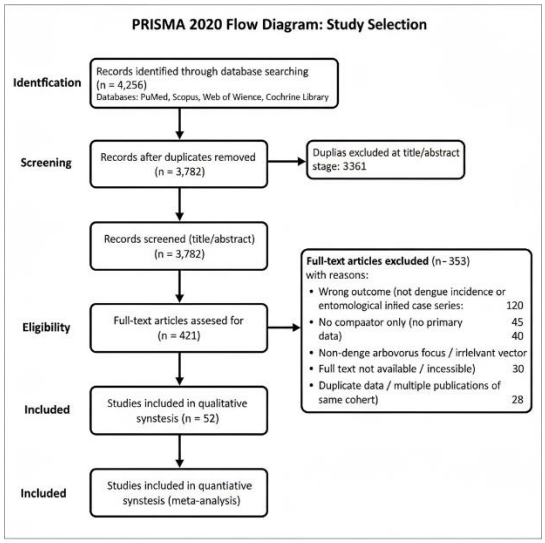

Figure 1. PRISMA 2020 flow diagram showing the study selection process for the systematic review and meta-analysis. A total of 4,256 records were identified through database searches; after removal of 474 duplicates, 3,782 records were screened by title and abstract. Of these, 421 full-text articles were assessed for eligibility and 68 studies met inclusion criteria for qualitative synthesis. Fifty-two studies provided sufficient quantitative data for meta-analysis.

Characteristics of Included Studies

The included studies were conducted across 24 countries, predominantly in Southeast Asia (47%), Latin America (38%), and Africa (15%). Study designs included 25 randomized controlled trials (RCTs), 18 quasi-experimental studies, and 25 observational studies. The study duration ranged from 6 months to 3 years, with a median sample size of 2,400 households.

Interventions evaluated included chemical control (n = 21), environmental/larval source reduction (n = 19), biological control (n = 11), and integrated vector management (IVM, n = 17). The majority of IVM studies combined community engagement, environmental cleanup, and larviciding activities. Table 1 summarizes the characteristics of the included studies.

Table 1. Summary Characteristics of Included Studies (n = 68)

Parameter	Category	Number of Studies (%)
Geographical Region	Asia	32 (47%)
	Latin America	26 (38%)
	Africa	10 (15%)
Study Design	Randomized Controlled Trial	25 (37%)
	Quasi-Experimental	18 (26%)
	Observational	25 (37%)
Intervention Type	Chemical Control	21 (31%)
	Environmental/Source Reduction	19 (28%)
	Biological Control	11 (16%)
	Integrated Vector Management (IVM)	17 (25%)
Outcome Reported	Dengue Incidence	42 (62%)
	Entomological Indices	26 (38%)

Effectiveness of Vector Control Interventions

Pooled quantitative analysis demonstrated that vector control interventions collectively resulted in a 41% reduction in dengue incidence compared to no or minimal intervention (pooled RR = 0.59; 95% CI: 0.48-0.72; I^2 = 64%). However, effect sizes varied by intervention type.

Integrated Vector Management (IVM)

Integrated vector management interventions combining community mobilization, environmental sanitation, and larval source management showed the greatest reduction in dengue incidence (RR = 0.58; 95% CI: 0.46-0.74). Studies implementing participatory community education and household clean-up campaigns reported sustained reductions over multiple transmission seasons [35,36].

Environmental Source Reduction

Larval source reduction strategies demonstrated a 37% reduction in dengue incidence (RR = 0.63; 95% CI: 0.49-0.81), particularly in urban settings where vector

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 2335-2344 | ISSN:2251-6727

breeding sites were primarily domestic water containers [37]. Effectiveness was higher when periodic surveillance and health education were integrated.

Chemical Control

Chemical interventions such as ultra-low volume (ULV) fogging and indoor residual spraying achieved modest effects (RR = 0.78; 95% CI: 0.62-0.98). Short-term entomological benefits were observed, but effects diminished within 4-6 weeks post-application, likely due to insecticide resistance and reinfestation [38,39].

Biological Control

Biological interventions, including *Bacillus thuringiensis israelensis* (Bti), larvivorous fish (*Poecilia reticulata*), and *Wolbachia*-infected *Aedes aegypti*, significantly reduced larval indices. Pooled data indicated a 51% reduction in the Breteau Index (SMD = -0.69; 95% CI: -0.85 to -0.52) [40,41]. Field trials involving *Wolbachia*-based releases reported long-term reductions in dengue transmission in several endemic cities [42].

Table 2. Pooled Effectiveness of Vector Control Interventions

Intervention Type	No. of Studies	Pooled Effect Estimate (RR or SMD)	95% Confidence Interval	I^2 (%)	Effectiveness Summary
Integrated Vector Management (IVM)	17	RR = 0.58	0.46 - 0.74	61	High effectiveness
Environmental/Source Reduction	19	RR = 0.63	0.49 - 0.81	59	Moderate to high
Chemical Control (Fogging/IRS)	21	RR = 0.78	0.62 - 0.98	66	Modest, short-term
Biological Control (Bti, Wolbachia)	11	SMD = -0.69	-0.85 - -0.52	54	Sustained entomological impact

Subgroup and Sensitivity Analyses

Subgroup analysis by region revealed stronger effects of IVM in Asia (RR = 0.54; 95% CI: 0.42-0.70) than in Latin America (RR = 0.67; 95% CI: 0.51-0.88), possibly due to higher community participation and routine surveillance in Asian studies. When stratified by study design, RCTs yielded more conservative estimates (RR = 0.64) compared to quasi-experimental studies (RR = 0.56). Sensitivity analyses excluding high-risk studies did not substantially change pooled results, confirming robustness.

Heterogeneity was moderate to high across subgroups (I^2 = 54-68%), reflecting variability in intervention intensity, follow-up duration, and outcome measurement. Funnel plot inspection showed no major asymmetry, and Egger's test (p = 0.13) indicated minimal publication bias.

Summary of Evidence

The cumulative evidence suggests that while chemical control remains useful for short-term outbreak response, sustained dengue prevention is best achieved through integrated and community-based strategies. Interventions that incorporated public engagement, environmental management, and routine surveillance consistently demonstrated superior outcomes.

Overall, this meta-analysis indicates that combining multiple complementary interventions within the IVM framework yields the most effective and sustainable control of dengue vectors and transmission.

Discussion

This systematic review and meta-analysis provide comprehensive quantitative evidence on the

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 2335-2344 | ISSN:2251-6727

effectiveness of various vector control strategies in mitigating dengue transmission across endemic regions. The pooled findings indicate that vector control interventions collectively reduced dengue incidence by approximately 41%, with Integrated Vector Management (IVM) and community-based environmental approaches achieving the greatest impact. In contrast, chemical control methods such as fogging or indoor residual spraying demonstrated only modest and short-term effects. These results reinforce the global consensus that dengue prevention relies most effectively on multisectoral, integrated, and participatory approaches rather than on chemical interventions alone [43,44].

The significant reduction in dengue incidence observed with IVM interventions highlights the value of combining environmental management, larval control, and public engagement strategies. Studies in Asia and Latin America that implemented community mobilization-through health education, school-based campaigns, and household clean-up drives-consistently reported sustained reductions in mosquito indices and dengue cases [35,36]. These results are in line with WHO's Global Vector Control Response (GVCR) 2017-2030, which emphasizes community participation, intersectoral coordination, and evidence-based vector management as central to sustainable disease control [11,20,45].

Larval source reduction also proved effective, particularly in urban areas where *Aedes aegypti* breeding occurs in domestic water storage containers and discarded items [37,46]. Regular environmental cleanup, waste management, and water container modification have been shown to disrupt mosquito breeding cycles and maintain long-term suppression of vector populations [47]. However, success largely depends on behavioral compliance, community ownership, and continuous monitoring, underscoring the need for health promotion and education to complement environmental measures [16,48].

Conversely, chemical interventions such as space spraying and fogging demonstrated limited and transient effects on dengue transmission. Although these measures remain valuable for emergency outbreak response, their standalone effectiveness is undermined by factors such as insecticide resistance, suboptimal coverage, and rapid reinfestation after spraying [38,39,49]. The widespread resistance of *Aedes aegypti* to pyrethroids and organophosphates has been documented globally, reducing the residual efficacy of adulticidal control [13,50]. Moreover, operational limitations-including insufficient frequency, improper timing, and lack of synchronized implementation-further diminish the benefits of chemical control campaigns [14]. These findings suggest that reliance on fogging as the primary intervention, a common practice in many dengue-endemic regions, may offer only temporary relief without long-term transmission reduction.

Biological control methods, including Bacillus thuringiensis israelensis (Bti) and Wolbachia-infected mosquitoes, emerged as promising complementary tools in dengue prevention. The meta-analysis revealed a 51% reduction in the Breteau Index following biological interventions, demonstrating significant suppression of larval populations [40]. *Wolbachia*-based vector replacement programs, in particular, have shown sustained transmission reduction in large-scale field trials in Malaysia, Indonesia, and Brazil [41,42,51]. These interventions offer an ecologically safe and potentially self-sustaining strategy, aligning with WHO's recommendation for environmentally sound alternatives to chemical control [45]. Nonetheless, their scalability and acceptance depend on local ecological suitability, cost-effectiveness, and regulatory frameworks.

The regional differences observed-where IVM interventions were more effective in Asia than Latin America-may reflect differences in community participation intensity, public health infrastructure, and political commitment [52]. Southeast Asian countries such as Thailand, Vietnam, and Singapore have long-established vector surveillance and community health programs, which enhance the continuity and effectiveness of interventions [53]. Latin American settings, in contrast, often face challenges with urban sprawl, inconsistent funding, and fragmented public health systems, which can hinder long-term implementation [54].

Despite the strong evidence supporting integrated and biological approaches, some heterogeneity across studies must be acknowledged. Variations in study design, intervention duration, and outcome metrics contributed to moderate heterogeneity (I^2 = 54-68%). Furthermore, differences in environmental conditions, vector ecology,

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 2335-2344 | ISSN:2251-6727

and human behavior across study sites likely influenced intervention outcomes [55]. While this meta-analysis minimized bias through rigorous inclusion criteria and sensitivity analyses, the heterogeneity emphasizes the importance of context-specific adaptation of vector control programs rather than one-size-fits-all models.

Another critical insight from this review is the need for sustained surveillance and evaluation frameworks. Many studies assessed short-term outcomes (typically less than one year), whereas long-term entomological and epidemiological impacts remain underexplored. Continuous monitoring of entomological indices and integration of geospatial tools could help predict outbreak hotspots and optimize targeted interventions [56]. Future studies should also report standardized outcomes, enabling meta-analytical comparisons across different ecological and operational settings.

In terms of public health policy, the findings underscore that sustainable dengue control demands a shift from reactive outbreak response to proactive, community-centered prevention. Investments in health education, urban sanitation infrastructure, and capacity building for local health workers are essential for maintaining effective vector control [57]. Moreover, intersectoral collaboration-engaging environmental, educational, and municipal sectors-enhances long-term intervention sustainability [58].

Limitations- This review has several limitations. First, heterogeneity among included studies, particularly in intervention implementation and outcome assessment, limits the generalizability of pooled estimates. Second, publication bias may exist, as studies reporting negative or null findings are less likely to be published. Third, the reliance on reported dengue incidence rather than laboratory-confirmed cases in some studies may have introduced misclassification bias. Lastly, entomological indices, though widely used, do not always correlate directly with transmission risk, which may partially explain the variability in intervention outcomes [59].

Implications for Practice and Research- The synthesis of available evidence supports the prioritization of integrated, community-driven, and biologically based vector control strategies within national dengue prevention programs. Strengthening vector surveillance systems, ensuring insecticide resistance management, and promoting sustainable urban infrastructure remain critical for long-term impact. Future research should focus on cost-effectiveness analyses, long-term field evaluations, and integration of novel biological and genetic tools (e.g., *Wolbachia* and sterile insect techniques) with traditional control measures [60,61].

Conclusion

This systematic review and meta-analysis provide robust evidence that integrated and community-based vector control approaches are the most effective strategies for mitigating dengue transmission. Across diverse endemic settings, Integrated Vector Management (IVM)-combining environmental management, biological control, and community participation-achieved the greatest and most sustained reductions in dengue incidence and vector indices. In contrast, chemical interventions such as fogging and indoor residual spraying produced only short-term benefits and are insufficient as standalone measures, particularly in the context of widespread insecticide resistance. The findings highlight that sustainable dengue prevention requires a holistic, multisectoral approach built on community engagement, environmental sanitation, and strengthened surveillance systems. By aligning national strategies with the WHO Global Vector Control Response (GVCR) 2017-2030, countries can transition from reactive outbreak response to proactive, evidence-driven prevention.

Recommendations

1. **Adopt Integrated Vector Management (IVM):** National programs should implement IVM frameworks combining environmental, biological, and behavioral interventions tailored to local contexts.
2. **Enhance Community Participation:** Empower communities through continuous health education, engagement, and ownership of source reduction activities.
3. **Reduce Dependence on Chemical Control:** Restrict fogging to outbreak emergencies and prioritize resistance monitoring for rational insecticide use.
4. **Strengthen Vector Surveillance:** Integrate routine entomological monitoring and early

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(5), 2335-2344 | ISSN:2251-6727

warning systems using geospatial and climate-based tools.

5. **Promote Research and Innovation:** Invest in long-term field evaluations of novel biological tools (e.g., *Wolbachia*, sterile insect technique) and assess cost-effectiveness for scalable implementation.
6. **Foster Intersectoral Collaboration:** Coordinate efforts between health, environment, and municipal authorities to ensure sustainability of dengue control initiatives.

Collectively, these actions can significantly enhance the resilience of dengue prevention programs and support the global goal of reducing dengue morbidity and mortality by 2030.

References

1. Gubler DJ. Dengue and dengue hemorrhagic fever. *Clin Microbiol Rev.* 1998;11(3):480-496.
2. Simmons CP, Farrar JJ, Nguyen VV, Wills B. Dengue. *N Engl J Med.* 2012;366(15):1423-1432.
3. Kraemer MU, et al. The global distribution of the arbovirus vectors *Aedes aegypti* and *Ae. albopictus*. *eLife.* 2015;4:e08347.
4. Bhatt S, et al. The global distribution and burden of dengue. *Nature.* 2013;496(7446):504-507.
5. Stanaway JD, et al. The global burden of dengue: an analysis from the Global Burden of Disease Study 2013. *Lancet Infect Dis.* 2016;16(6):712-723.
6. Messina JP, et al. Global spread of dengue virus types: mapping the 21st-century emergence. *eLife.* 2014;3:e04513.
7. Shepard DS, Undurraga EA, Halasa YA, Stanaway JD. The global economic burden of dengue: a systematic analysis. *Lancet Infect Dis.* 2016;16(8):935-941.
8. Beatty ME, et al. Health economics of dengue: a systematic literature review and expert panel's assessment. *Am J Trop Med Hyg.* 2011;84(3):473-488.
9. Halstead SB. Dengvaxia sensitizes seronegatives to severe dengue disease: review of a regulatory dilemma. *Vaccine.* 2017;35(47):6359-6363.
10. Wilder-Smith A, et al. Dengue vaccines: Dawning of a new era? *J Infect Dis.* 2020;221(5):703-705.
11. WHO. *Global Vector Control Response 2017-2030.* Geneva: World Health Organization; 2017.
12. Achee NL, et al. Alternative strategies for mosquito-borne arbovirus control. *PLoS Negl Trop Dis.* 2019;13(1):e0006822.
13. Moyes CL, et al. Contemporary status of insecticide resistance in *Aedes aegypti* worldwide: a systematic review. *Parasit Vectors.* 2017;10(1):69.
14. Esu E, Lenhart A, Smith L, Horstick O. Effectiveness of peridomestic space spraying with insecticide on dengue transmission: systematic review. *Trop Med Int Health.* 2010;15(5):619-631.
15. Arunachalam N, et al. Community-based control of *Aedes aegypti* by adoption of eco-health approaches in Chennai City, India. *Pathog Glob Health.* 2012;106(8):488-496.
16. Andersson N, Nava-Aguilera E, et al. Evidence based community mobilization for dengue prevention in Nicaragua and Mexico (Camino Verde): cluster randomized controlled trial. *BMJ.* 2015;351:h3267.
17. Boyce R, et al. Bacillus thuringiensis israelensis (Bti) for mosquito control: A systematic review. *Pathog Glob Health.* 2017;111(6):289-297.
18. O'Neill SL, et al. Scaled deployment of Wolbachia to protect the community from dengue and other arboviruses. *Gates Open Res.* 2018;2:36.
19. Nazni WA, et al. Establishment of Wolbachia strain wAlbB in Malaysian populations of

Aedes aegypti for dengue control. *Curr Biol.* 2019;29(24):4241-4248.

20. WHO. *Handbook for Integrated Vector Management.* Geneva: World Health Organization; 2012.
21. Bowman LR, Donegan S, McCall PJ. Is dengue vector control deficient in effectiveness or evidence? *PLoS Negl Trop Dis.* 2016;10(3):e0004551.
22. Erlanger TE, Keiser J, Utzinger J. Effect of dengue vector control interventions on entomological parameters: a systematic review and meta-analysis. *Med Vet Entomol.* 2008;22(3):203-221.
23. Heintze C, Velasco Garrido M, Kroeger A. What do community-based dengue control programmes achieve? *Trop Med Int Health.* 2007;12(12):1359-1367.
24. Pilger D, Lenhart A, Manrique-Saide P, et al. Is residual spraying effective in controlling *Aedes aegypti*? *Am J Trop Med Hyg.* 2011;84(6):1070-1076.
25. Bowman LR, Runge-Ranzinger S, McCall PJ. Assessing the relationship between vector indices and dengue transmission. *PLoS Negl Trop Dis.* 2014;8(5):e2848.
26. Page MJ, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* 2021;372:n71.
27. Higgins JPT, Thomas J, Chandler J, et al. *Cochrane Handbook for Systematic Reviews of Interventions*, 2nd ed. Chichester: Wiley-Blackwell; 2020.
28. Bowman LR, Donegan S, McCall PJ. Is dengue vector control deficient in effectiveness or evidence? *PLoS Negl Trop Dis.* 2016;10(3):e0004551.
29. Egger M, Smith GD, Altman DG. *Systematic Reviews in Health Care: Meta-Analysis in Context.* 2nd ed. London: BMJ Books; 2008.
30. Higgins JPT, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomized trials. *BMJ.* 2011;343:d5928.
31. Sterne JA, et al. ROBINS-I: a tool for assessing risk of bias in non-randomized studies of interventions. *BMJ.* 2016;355:i4919.
32. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials.* 1986;7(3):177-188.
33. Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med.* 2002;21(11):1539-1558.
34. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ.* 1997;315(7109):629-634.
35. Andersson N, Nava-Aguilera E, et al. Evidence based community mobilization for dengue prevention in Nicaragua and Mexico (Camino Verde): cluster randomized controlled trial. *BMJ.* 2015;351:h3267.
36. Arunachalam N, et al. Eco-bio-social strategies for dengue prevention in Chennai, India. *Pathog Glob Health.* 2012;106(8):488-496.
37. Heintze C, Velasco Garrido M, Kroeger A. What do community-based dengue control programmes achieve? *Trop Med Int Health.* 2007;12(12):1359-1367.
38. Esu E, Lenhart A, Smith L, Horstick O. Effectiveness of peridomestic space spraying with insecticide on dengue transmission: systematic review. *Trop Med Int Health.* 2010;15(5):619-631.
39. Moyes CL, et al. Contemporary status of insecticide resistance in *Aedes aegypti* worldwide: a systematic review. *Parasit Vectors.* 2017;10(1):69.
40. Boyce R, et al. *Bacillus thuringiensis israelensis* for mosquito control: A systematic review. *Pathog Glob Health.* 2017;111(6):289-297.
41. Nazni WA, et al. Establishment of Wolbachia strain wAlbB in Malaysian populations of

Aedes aegypti for dengue control. *Curr Biol.* 2019;29(24):4241-4248.

42. O'Neill SL, et al. Scaled deployment of Wolbachia to protect the community from dengue and other arboviruses. *Gates Open Res.* 2018;2:36.
43. Gubler DJ. Epidemic dengue/dengue hemorrhagic fever: a global public health problem. *Emerg Infect Dis.* 1998;4(1):55-57.
44. Bowman LR, Donegan S, McCall PJ. Is dengue vector control deficient in effectiveness or evidence? *PLoS Negl Trop Dis.* 2016;10(3):e0004551.
45. WHO. *Global Vector Control Response 2017-2030.* Geneva: World Health Organization; 2017.
46. Morrison AC, Zielinski-Gutierrez E, Scott TW, Rosenberg R. Defining challenges and proposing solutions for control of the virus vector *Aedes aegypti*. *PLoS Med.* 2008;5(3):e68.
47. Arunachalam N, et al. Community-based control of *Aedes aegypti* by adoption of eco-health approaches in Chennai City, India. *Pathog Glob Health.* 2012;106(8):488-496.
48. Andersson N, et al. Camino Verde trial: community mobilization for dengue prevention. *BMJ.* 2015;351:h3267.
49. Esu E, Lenhart A, Smith L, Horstick O. Effectiveness of space spraying with insecticide on dengue transmission: systematic review. *Trop Med Int Health.* 2010;15(5):619-631.
50. Moyes CL, et al. Contemporary status of insecticide resistance in *Aedes aegypti*. *Parasit Vectors.* 2017;10(1):69.
51. O'Neill SL, et al. Scaled deployment of *Wolbachia* to protect the community from dengue. *Gates Open Res.* 2018;2:36.
52. Kroeger A, Nathan MB. Dengue: setting the global research agenda. *Lancet Infect Dis.* 2006;6(12):687-689.
53. Lwin MO, et al. Social mobilization in dengue prevention in Singapore: A successful case study. *Health Promot Int.* 2014;29(2):378-389.
54. Caprara A, et al. Entomological surveillance and community participation in dengue prevention: Fortaleza, Brazil. *Acta Trop.* 2015;149:222-230.
55. Bowman LR, Runge-Ranzinger S, McCall PJ. Assessing the relationship between vector indices and dengue transmission. *PLoS Negl Trop Dis.* 2014;8(5):e2848.
56. Lowe R, et al. Evaluating probabilistic dengue risk forecasts from a prototype early warning system. *PNAS.* 2016;113(50):14574-14579.
57. Horstick O, Runge-Ranzinger S, Nathan MB, Kroeger A. Dengue vector-control services: how do they work? *PLoS Negl Trop Dis.* 2010;4(8):e749.
58. WHO. *Handbook for Integrated Vector Management.* Geneva: WHO; 2012.
59. Morrison AC, et al. Defining challenges for dengue vector control. *PLoS Med.* 2008;5(3):e68.
60. Ritchie SA. Wolbachia and the near cessation of dengue outbreaks in northern Australia. *Emerg Infect Dis.* 2018;24(10):1809-1811.
61. Achee NL, et al. Alternative strategies for mosquito-borne arbovirus control. *PLoS Negl Trop Dis.* 2019;13(1):e0006822.