



# Effectiveness of stand-alone anti-adult mosquito control strategies against *Aedes*-borne diseases: scoping review with meta-analysis

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**Background:** The world is witnessing the emergence of infections transmitted by *Aedes* mosquitoes. However, preventing large outbreaks challenges the health systems of endemic countries. Targeting infected adult *Aedes* mosquitoes may be a better means for resource-constrained health systems where integrated vector control may be less feasible. We reviewed the evidence of the effectiveness of stand-alone adult mosquito control measures against *Aedes* mosquito-borne diseases in this scoping review and meta-analysis.

**Methods:** The MEDLINE, Embase, Scopus and Cochrane Library (Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials [CENTRAL] and Cochrane Methodology Register) electronic bibliographic databases for randomised controlled trials (randomised for individual or cluster of houses), blinded at any level or open-label, conducted anywhere in the world during the period 1 December 2012 to 31 November 2022 and published in the English language. The search terms included only terms relating to or describing the intervention, combined with the Cochrane/MEDLINE filter for the eligible studies. The searches were rerun just before the final analyses and further studies were retrieved for inclusion. A narrative synthesis of the findings from the included studies was provided. Risk of bias (quality) assessment was done using Cochrane's risk of bias assessment tool. Summaries of the intervention effects for each study were provided by calculating the odds ratios for dichotomous outcomes and standardised mean differences for continuous outcomes. Data analysis was done using Review Manager version 5.4. Heterogeneity was assessed using the Cochrane  $\chi^2$  test,  $I^2$  statistic and  $\tau^2$  test. Potential publication bias was evaluated and illustrated using funnel plots. The data were pooled using a fixed/random effects meta-analysis and the effect measures, their 95% confidence intervals (CIs) and two-sided *p*-values for each outcome. Subgroup analyses were used as the sensitivity analysis. Results were plotted using forest plots for all outcome variables in the study.

**Results:** The standardised mean reduction in the number of indoor adult *Aedes aegypti* mosquitoes was 1.81 (95% CI 0.76 to 2.86) because of anti-adult interventions. The reduction in the incidence of dengue in houses deploying measures against adult *A. aegypti* mosquitoes was 28%, but statistically not significant (pooled odds ratio [Mantel-Haenszel, random]) was 0.72 (95% CI 0.28 to 1.86). However, the effect measure could be influenced by co-interventions like decreased insecticide actions and lack of community engagement. Subgroup analysis revealed that all the measures targeting adult *Aedes* mosquitoes are effective in reducing *A. aegypti* abundance.

**Conclusions:** Interventions targeting adult *Aedes* mosquitoes are significantly reducing the indoor adult *A. aegypti* abundance and hence the risk of *Aedes*-borne infections. However, the effect could decrease over time and care should be exercised in the sustainability of such interventions. More evidence should be generated for



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epidemiological outcomes such as a reduction in infections rather than entomological outcomes such as larval indices and vector abundance.

**Keywords:** adult mosquito control, *Aedes* control, *Aedes* mosquito-borne disease control, anti-adult mosquito control, meta-analysis, scoping review

## Introduction

Culicine mosquitoes, specifically *Aedes aegypti* and *Aedes albopictus*, are the principal vectors of emerging arboviral infections, dengue, chikungunya, yellow fever and Zika.<sup>1</sup> The global burden of *Aedes*-borne infections has increased dramatically in recent decades.<sup>1</sup> Severe dengue is a life-threatening medical condition, while chikungunya is a chronic, debilitating disease.<sup>3,4</sup> The emergence of Zika infection was declared a public health emergency of international concern by the World Health Organization (WHO) following a large outbreak in Brazil that resulted in an epidemic of microcephaly in newborns in 2015.<sup>2,6</sup> India is experiencing a high burden from the major vectors of all *Aedes*-borne infections, *A. aegypti* and *A. albopictus*, and is endemic for all these diseases except yellow fever.<sup>7</sup>

Traits like activity during the daytime, sensitivity to movements of the host, multiple host tropism, survival of desiccated/dry eggs and ability to domesticate make *Aedes* well-adapted for survival near human dwellings and increase the vectorial capacity of the mosquito.<sup>3,8,9</sup> *A. aegypti* preferentially feeds on humans even in the presence of other hosts.<sup>4</sup> The transition towards a hot and humid climate, intermittent rainfall and tropicalization of temperate locations because of climate change will increase the burden of *Aedes*-borne diseases in the coming years.<sup>5</sup>

Integrated vector management (IVM) incorporates overarching strategies combining antilarval and anti-adult measures, environmental modifications and personal protective methods.<sup>6</sup> Antilarval measures stabilize the mosquito population even before the start of the outbreak and anti-adult measures suppress the number of infected mosquitoes amid outbreaks. Antilarval measures like source reduction are time-tested strategies to alleviate the burden of the mosquito population during interepidemic periods.<sup>7,13</sup> However, anti-adult measures that are aimed at already infected adult mosquitoes may be more effective at the peak of an ongoing outbreak. These measures serve as a powerful outbreak response strategy to yield rapid results. There are multiple methods, including fixing nets on doors and windows to deny mosquitoes entry to living spaces, indoor residual spraying, installation of autocidal gravid mosquito traps, fogging and ultra-low-volume spraying using insecticides. But these techniques can have unwanted side effects, such as environmental contamination or the killing of other insects (e.g. in the case of ultra-low-volume spraying).<sup>8</sup>

Field trials that measure the effectiveness of stand-alone anti-adult measures have provided conflicting results.<sup>9</sup> A recent study by Morrison et al.<sup>10</sup> reported that spatial repellents are effective against *Aedes*-borne infections. In contrast, Lenhart et al.<sup>11</sup> observed that insecticide-impregnated nets do not result in long-term protection against dengue. As diverse anti-adult interven-

tions are available, the effect size can vary across different trials, so a proper synthesis of evidence is necessary for informed policy-making. We reviewed the evidence of the effectiveness of stand-alone adult mosquito control measures against *Aedes*-borne diseases in this scoping review and meta-analysis.

## Methods

### Search strategy and selection criteria

The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (<https://www.prisma-statement.org/scoping>). The proposal was registered in PROSPERO (CRD42022340160), an international prospective register for systematic reviews. The electronic bibliographic databases searched were MEDLINE, Embase, Scopus and the Cochrane Library (Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials (CENTRAL) and Cochrane Methodology Register). In PubMed, search terms connected by Boolean operators were used for a general search (URL: <https://pubmed.ncbi.nlm.nih.gov/?term=%28trap+OR+spraying+OR+fogging+OR+ULV+OR+IRS+OR+ISS+%29+AND+%28dengue+OR+chikungunya+OR+zika+OR+yellow+fever%29>). Along with the primary search, we used all possible combinations of 'infection' (dengue, chikungunya, Zika and yellow fever) and 'anti-adult mosquito control measure' (trap, spraying, fogging, ULV, IRS/indoor residual spray and ISS/indoor space spray) pairs in the advanced search function of PubMed. The searches were independently conducted by two investigators (TSA and JV). Each study identified in the search was evaluated against the following predetermined criteria:

#### Participants/population

People inhabiting areas prone to dengue, chikungunya, Zika or yellow fever and any stand-alone anti-adult measures used against *Aedes*.

#### Interventions/exposures

Interventions were any stand-alone anti-adult measures for controlling *Aedes* mosquito-borne diseases, which could be vector traps (gravitraps or sentinel traps, not ovitraps) or targeted insecticide application (application of insecticides to surfaces like bed nets, cloths and walls or in spaces inside or outside of buildings) or general application of insecticides like fogging or ultra-low-volume spraying.

Integrated vector management (IVM) techniques that combine antilarval methods with anti-adult measures were excluded, as it becomes impossible to measure the stand-alone impact



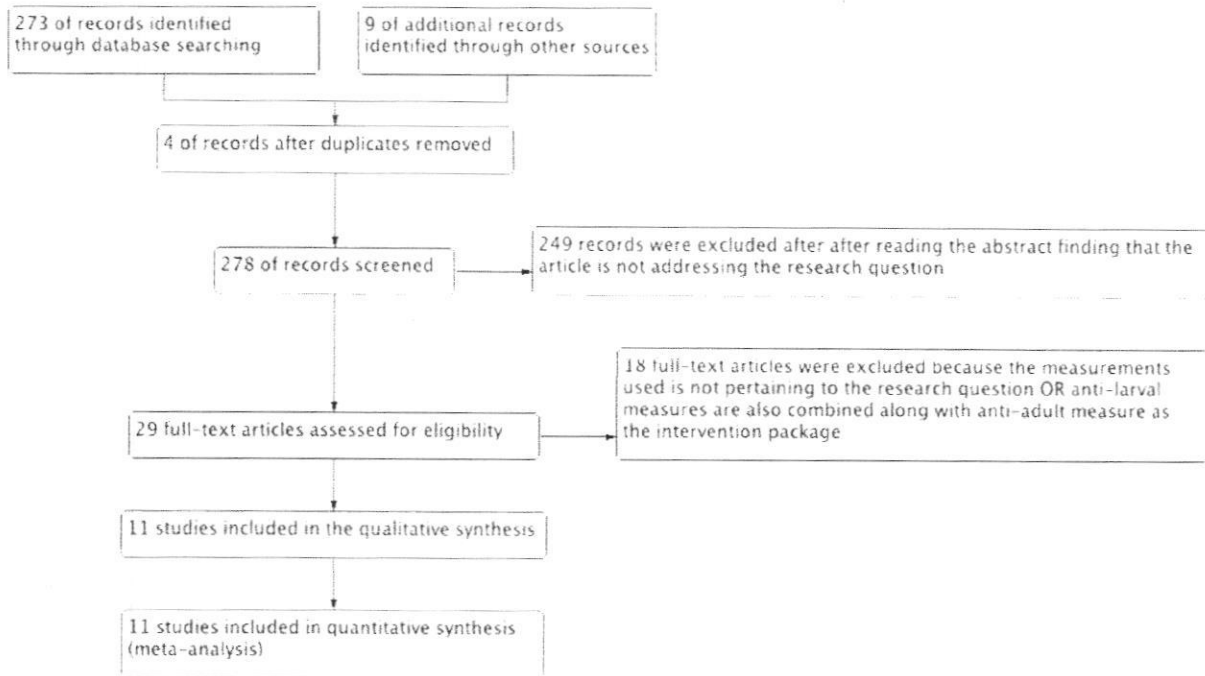


Figure 1. PRISMA flow chart of the review process.

of the anti-adult measures. Only the use of insecticides against adult *Aedes* mosquitoes was considered. Techniques like *Wolbachia* or sterile males were not considered, even if they were applied to adults, because their effect is mainly on larval density.

#### Comparators/controls

People inhabiting areas prone to dengue, chikungunya, Zika or yellow fever and where any anti-adult measures are not used against *Aedes* were used as comparators/controls.

#### Types of studies included in the review

We examined randomised controlled trials (RCTs; individual randomization or cluster randomization) in a field setting conducted anywhere around the world during the period 1 December 2012 to 31 November 2022. We chose this arbitrary time frame to include recent evidence that could help us answer our research question. Open label or studies blinded at any level were included. Only publications in English were considered. Grey literature, including conference proceedings and unpublished reports, was not included in this review.

#### Primary outcomes

The incidence of dengue, measured as a change in seroprevalence or detection of a new infection, was the primary outcome. There were no trials testing the effectiveness of adult *Aedes* control measures against chikungunya, Zika or yellow fever. Some trials measured the direct impact of the intervention on indoor

*A. aegypti* abundance. Hence the two primary outcomes of the study were seroconversion/incidence of dengue and indoor *A. aegypti* abundance.

#### Secondary outcome

Larval indices can be indicative of the effect of anti-mosquito activities. The Breteau Index (BI), calculated for the locations of interventions compared with the comparator, was considered as a secondary outcome for this analysis. We included larval indices as a secondary outcome because an indirect effect on larval indices is anticipated when anti-adult measures are employed. Larval indices are also widely used as proxies for vector surveillance and vector control program monitoring.

#### Data extraction and quality assessments

Figure 1 depicts the data extraction process. Titles of studies retrieved using the search strategy and those from additional sources were screened independently by two review authors. Studies that potentially met the inclusion criteria were identified. The abstracts of the selected studies were assessed by the reviewers in the second stage and independent lists of eligible studies were prepared. The two reviewers were blinded. An adjudicator checked the list of studies prepared by each reviewer and decided upon the completeness of reviews at this stage. The full text of the potentially eligible studies was retrieved and independently assessed for eligibility at the third stage of the review process. Any disagreement between the team members over the eligibility of any study was resolved through discussion. A standardised, pre-piloted form was used to extract data from the included



studies for assessment of study quality and evidence synthesis. The extracted information included study setting, study population and participant demographics and baseline characteristics, details of the intervention and control conditions, study methodology, recruitment and study completion rates, outcomes and times of measurement, indicators of acceptability to users, suggested mechanisms of intervention action and information for assessment of the risk of bias.

The risk of bias was assessed independently by two review authors using Cochrane's risk of bias assessment tool.

Disagreements between the review authors over the risk of bias in particular studies were resolved by discussion, with the involvement of a third review author where necessary. The overall risk of bias for all included studies was qualitatively evaluated and provided in a colour-coded risk of bias matrix.

### Data synthesis

Data analysis was done using Review Manager version 5.4 (Cochrane Collaboration, London, UK). Quantitative data were extracted from all the candidate studies. Summaries of the intervention effects for each study were provided by calculating odds ratios (ORs) for dichotomous outcomes (seroconversion/infection as the outcome) and standardised mean differences for continuous outcomes (indoor *A. aegypti* abundance and the BI). Heterogeneity was assessed using the Cochrane  $\chi^2$  test,  $I^2$  statistic and  $\tau^2$  test. Potential publication bias was evaluated and illustrated using a funnel plot. After checking for heterogeneity, the data were pooled using a fixed/random effects meta-analysis and the effect measures, their 95% confidence intervals (CIs) and two-sided p-values for each outcome. Subgroup analyses were used as the sensitivity analysis. Results were plotted using forest plots for all outcome variables in the study.

Sensitivity analyses were performed to identify interventions that are more likely to influence the pooled effect measures.

### Ethics

As this study is a scoping review of published literature and does not involve human participants or unpublished personal data, ethical approval was not required. However, the Institutional Research Committee of Government Medical College, Manjeri, scrutinised the study proposal and exempted it from review by the Human Ethics Committee.

### Results

The 11 studies selected for the systematic review and meta-analysis are presented in Table 1. Candidate studies were conducted in North America (Mexico), South America (Brazil, Peru and Venezuela) and Asia (Thailand and Indonesia). There were no studies reported from Africa. Indian studies were also absent.

### Design, interventions and outcomes

Houses were the sampling units for all the studies. All except one<sup>16</sup> were cluster RCTs. Supplementary File Part 1, Table S1 details the clusters used in each study. The anti-adult measures used were house screening with insecticide screening

nets,<sup>12,16,19</sup> areal ultra-low-volume insecticide application<sup>13</sup>, mass trapping with BG-Sentinel traps,<sup>14,15</sup> insecticide-treated curtains<sup>11,17,18</sup> and insecticide-based space repellent<sup>10,20</sup>. Five studies assessed infection-related outcome measures. Two studies<sup>14,15</sup> used acute infection evidenced by immunoglobulin M (IgM) enzyme-linked immunosorbent assay (ELISA) positivity for dengue. The others<sup>10,11,18</sup> used indirect IgG antibody-based seroconversion.

Eight studies recorded the impact on adult *A. aegypti* abundance using adult indoor resting *Aedes* mosquitoes collected from all rooms with Prokopack aspirators for 30 min. Three studies<sup>11,17,18</sup> used the larval BI, the average number of breeding sites per 100 houses.

We used BI only as a secondary outcome measure because we were more interested in the impact on potentially infected adult mosquitoes and the reduction in infection.

One of the studies<sup>18</sup> had more than two arms, so the comparison between the anti-adult measure (insecticide-impregnated curtain) and placebo was used in the analysis.

All the studies except one were open-label trials. The appraisal of the risk of bias based on Cochrane's risk of bias assessment checklist was detailed in part 2 of the Supplementary File and summarised in Figures S1 and S2.

### Effectiveness of anti-adult measures to prevent dengue infection or to retard seroconversion (primary outcome)

Figure 2 is a forest plot depicting the effectiveness of anti-adult measures against *Aedes* mosquitos to prevent dengue infection or to retard seroconversion (primary outcome). A random effects meta-analysis was used, as there is significant heterogeneity ( $I^2=96\%$ ,  $\tau^2=0.79$  and Cochran's Q is significant with  $p<0.05$ ). The studies with maximum weight, 29.4%<sup>11</sup> and 29.3%<sup>10</sup> had conflicting results. The pooled OR (Mantel-Haenszel, random) was 0.72 (95% CI 0.28 to 1.86). The point estimate of the pooled OR showed 28% protection against new dengue infections in houses deploying anti-adult measures against *Aedes*, but the effectiveness was not statistically significant.

### Effectiveness of anti-adult measures to reduce indoor adult *A. aegypti* abundance (primary outcome)

Figure 3 is a forest plot depicting the effectiveness of anti-adult measures against indoor adult *A. aegypti* abundance (primary outcome). A random effects meta-analysis was used ( $I^2=100\%$ ,  $\tau^2=2.56$  and Cochran's Q is significant with  $p<0.05$ ) to assimilate standardised mean differences of the primary outcome. The *A. aegypti* abundance was lower than that of the comparator houses in all the studies and the pooled effect measure ( $-1.81$  [95% CI  $-2.86$  to  $-0.76$ ]) was statistically significant.

### Effectiveness of anti-adult measures to reduce the BI (secondary outcome)

The results are presented in the Supplementary File. Figure S3 is a forest plot depicting the effectiveness of anti-adult measures against *Aedes* mosquitoes in reducing the BI. The pooled standardised mean difference ( $-0.07$  [95% CI  $-0.55$  to  $0.41$ ]) was negligible.



**Table 1.** Characteristics of the included studies.

| Study                                    | Country/continent       | Design                   | Intervention  | Outcome (s)   |
|--|-------------------------|--------------------------|---|---|
| Che-Medoza et al. 2018 <sup>12</sup>     | Mexico/North America    | Cluster RCT of houses    | House screening with insecticide-treated screening nets | <i>A. aegypti</i> abundance   |
| Correa-Morales et al. 2018 <sup>13</sup> | Mexico/North America    | Cluster RCT of houses    | Aerial ultra-low volume insecticide application         | <i>A. aegypti</i> abundance   |
| Degener et al. 2014 <sup>14</sup>        | Brazil/South America    | Cluster RCT of houses    | Mass trapping with the BG-Sentinel trap                 | <i>A. aegypti</i> abundance and dengue virus IgM antibody detection |
| Degener et al. 2015 <sup>15</sup>        | Brazil/South America    | Cluster RCT of houses    | Mass trapping with the BG-Sentinel trap                 | <i>A. aegypti</i> abundance and dengue virus IgM antibody detection |
| Devine et al. 2021 <sup>16</sup>         | Mexico/North America    | RCT of individual houses | House screening with insecticide-treated screening nets | <i>A. aegypti</i> abundance   |
| Lenhart et al. 2013 <sup>17</sup>        | Thailand/Asia           | Cluster RCT of houses    | Insecticide-treated curtains                            | BI  |
| Lenhart et al. 2020 <sup>11</sup>        | Peru/South America      | Cluster RCT of houses    | Insecticide-treated curtains                            | BI and dengue virus seroconversion                                  |
| Lenhart et al. 2022 <sup>18</sup>        | Venezuela/South America | Cluster RCT of houses    | Insecticide-treated curtains                            | BI and dengue virus seroconversion                                  |
| Manrique-Saide et al. 2021 <sup>19</sup> | Mexico/North America    | Cluster RCT of houses    | House screening with insecticide-treated screening nets | <i>A. aegypti</i> abundance   |
| Morrison et al. 2022 <sup>10</sup>       | Peru/South America      | Cluster RCT of houses    | Insecticide-based space repellent                       | <i>A. aegypti</i> abundance and dengue virus seroconversion         |
| Permana et al. 2022 <sup>20</sup>        | Indonesia/Asia          | Cluster RCT of houses    | Insecticide-based space repellent                       | <i>A. aegypti</i> abundance   |

### Publication bias

Funnel plots (Figures 4 and 5, Figure S4) depict the effect measures of individual studies around the pooled estimates. No marked publication bias was noted for the outcomes of dengue infection/seroconversion (Figure 4) and BI (Figure S4). For indoor adult *A. aegypti* abundance (Figure 5), the funnel has mild tapering on the right-hand side, indicating a void of studies with high effect sizes.

### Subgroup analysis

#### Effectiveness of anti-adult measures to prevent dengue infection or to retard seroconversion excluding insecticide-impregnated curtains

Contrary to other studies, Lenhart et al.<sup>11</sup> found a significantly increased risk of dengue infection in the intervention group. The study argued that the effect of impregnation of curtains with insecticides may wane over time and people residing in those houses may neglect other modes of mosquito control because of

a false sense of security. Thus we conducted a subgroup analysis excluding the studies reporting insecticide impregnation of curtains (Figure S5). It showed interventions other than insecticide-impregnated curtains (BG-Sentinel trap and spatial application of insecticides) offered significant protection from dengue infection (OR 0.47 [95% CI 0.39 to 0.57]).

#### Effectiveness of specific anti-adult measures in the reduction of indoor adult *A. aegypti* abundance

Figures S6–S8 show the effectiveness of insecticide-treated screening nets, spatial application of insecticides or repellents and BG-Sentinel traps, respectively, on indoor adult *A. aegypti* abundance. All types of interventions significantly reduced the number of indoor *Aedes* mosquitoes. The standardised mean difference of insecticide-treated screening nets, spatial application of insecticides or repellents and BG-Sentinel traps was  $-3.36$  (95% CI  $-6.55$  to  $-0.16$ ),  $1.77$  (95% CI  $-3.57$  to  $0.04$ ) and  $-0.35$  (95% CI  $-0.49$  to  $-0.22$ ), respectively.



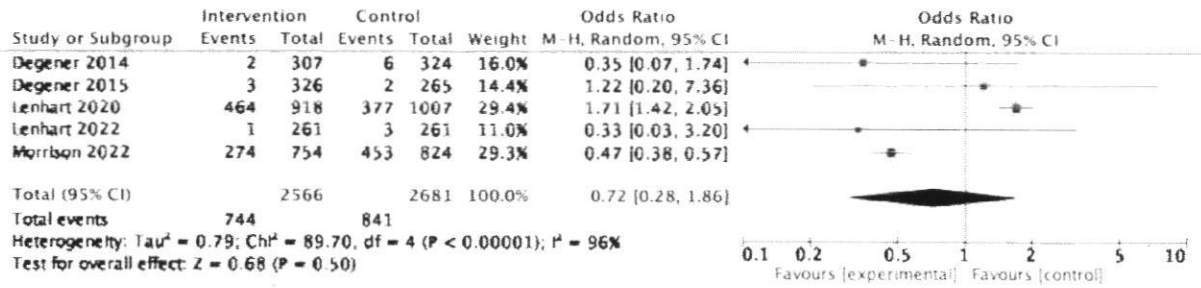


Figure 2. Forest plot depicting the effectiveness of anti-adult measures to prevent dengue infection or retard seroconversion.

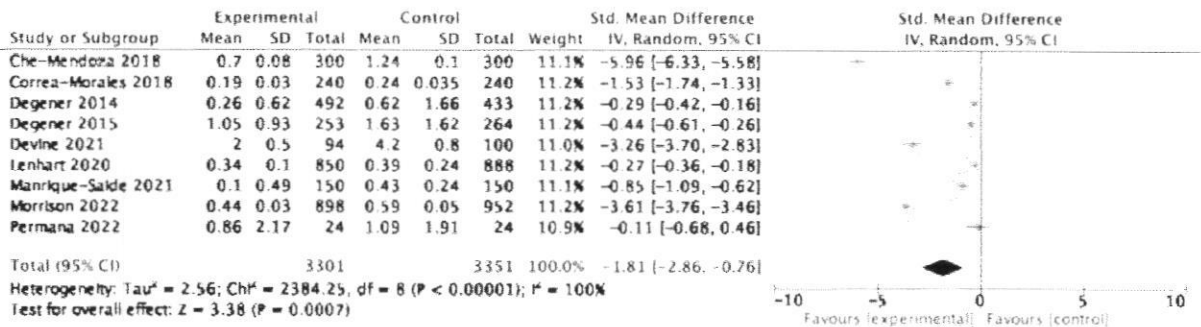


Figure 3. Forest plot depicting the effectiveness of anti-adult measures to reduce adult *A. aegypti* abundance.

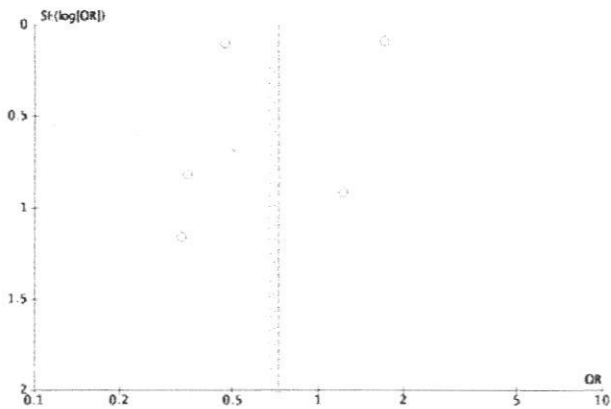


Figure 4. Funnel plot for effect measuring new dengue infection/seroconversion.

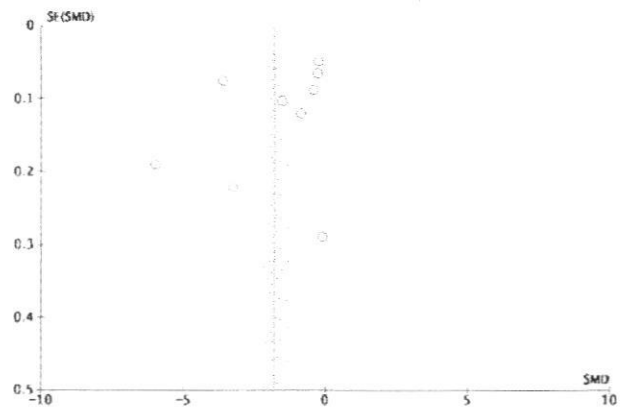


Figure 5. Funnel plot for effect measuring indoor adult *A. aegypti* abundance.

### Discussion

The review evaluated the effect of stand-alone anti-adult measures targeting *Aedes* mosquitoes on the mitigation of dengue infection and the reduction in indoor *A. aegypti* abundance. The pooled effect on the reduction of dengue was 28%, but only a few studies measured it; there were conflicting results, and the difference was not statistically significant. However, the effect on the indoor adult *A. aegypti* population was universal, substantial and statistically significant. The interventions had little impact on the larval indices. Anti-adult measures achieve the goal of reducing

*Aedes* mosquito-borne diseases by reducing the mosquito population, especially that of *A. aegypti*, in indoor domestic spaces.<sup>11</sup> The number and proportion of infected mosquitoes in this population during outbreaks is high, so a reduction in the indoor adult *A. aegypti* population is a surrogate measure for its impact on *Aedes*-borne diseases. However, studies that measure the direct impact of stand-alone anti-adult measures on *Aedes*-borne diseases are rare and are limited to dengue. We urge researchers to conduct more studies on the role of anti-adult measures in reducing dengue, chikungunya, yellow fever and Zika because of the emergence of *Aedes*-borne diseases.



Insecticide-impregnated window/door nets or BG-Sentinel traps provided a 50–75% reduction in the incidence of dengue infection.<sup>10,14</sup> One study reported a paradoxically high incidence of dengue fever in houses where insecticide-impregnated curtains were installed. The action of insecticides wanes over time, and a false sense of security might result in neglect of other mosquito control measures.<sup>11</sup> The existence or development of insecticide resistance can also contribute to the decreased effect of the intervention.<sup>21</sup> Hence indoor residual spraying with insecticides and insecticide impregnation of curtains may not be protective in the long run.<sup>22,23</sup> The finding reinforces the importance of community engagement in sustaining the effect of these interventions.<sup>24,25</sup>

The reduction of indoor adult *A. aegypti* abundance after the interventions was found to be marked. Sensitivity analysis showed that all interventions targeting adult *Aedes* mosquitoes resulted in a significant reduction of this parameter. The presence of indoor adult *A. aegypti* mosquitoes is a decisive factor in spreading *Aedes*-borne infections.<sup>26</sup> The percentage reduction in the candidate studies because of the interventions ranged from 20% to 75% of the total indoor adult *A. aegypti* mosquitoes per household (Figure 3). All types of interventions targeting the adult *Aedes* mosquitoes, including insecticide-treated nets, spatial application of insecticides/repellents and mosquito traps, significantly reduced the burden of indoor *Aedes* mosquitoes, resulting in lower disease transmission. We could not evaluate the specific impact of targeted indoor residual spray as an intervention because of the paucity of controlled trials fulfilling the eligibility criteria of our study. However, the evidence being accumulated favours targeted indoor residual spraying, which combines the bionomics of indoor *Aedes* mosquitoes with the residual nature of the insecticide.<sup>31</sup>

### Temporal and spatial distribution of included studies

The timeline of publications ranged from 2013 to 2022, but most of the included studies (6/11) were published in 2020–2022. Studies done in African and Indian settings were absent. According to the WHO, the Americas, Southeast Asia and Western Pacific regions are the most seriously affected by *Aedes*-borne infection, with Asia representing around 70% of the global burden.<sup>27</sup> A serosurvey suggested that the infections are underreported in many countries in the Global South.<sup>28</sup> Such paucity of information is seen in the spatial distribution of the countries of origin of the candidate studies. The variations in the health system priorities, availability of research funding, lack of investment in research and high publication costs could be reasons for the underrepresentation of research from Africa and India.<sup>32</sup>

### Heterogeneity

The  $I^2$  statistics showed marked heterogeneity between the studies. We used random effects meta-analysis to accommodate the statistical heterogeneity. Many factors might have contributed to the large differences in the effect. The studies came from different countries and the epidemiological situation may be different in different geographical settings, influencing the effect of interventions. The time of administration of interventions, whether it was during an outcome or not, can also cause heterogeneity.<sup>29,30</sup>

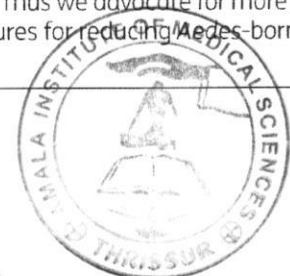
Variations in the measurement of exposure and outcomes in different studies contributed to methodological heterogeneity. For example, most of the studies quantified the incidence of new dengue infection as a change in seroprevalence, but one among them reported new fevers with an IgM ELISA positive for dengue. Cluster randomization was used in all studies except Devine et al.,<sup>16</sup> which used randomization at the individual level. The average number of people per cluster in the included studies ranged between 30 and 250,<sup>17</sup> contributing to differences in intra-cluster correlations and hence to the precision of the outcome measures.<sup>13</sup>

### Strengths and weaknesses

The current scoping review and meta-analysis is the first meta-analysis study exploring the effectiveness of stand-alone interventions targeting adult *Aedes* mosquitoes. The current analysis uses direct impacts of the control activities, like indoor adult *A. aegypti* abundance and disease occurrence as the outcome; most of the comparable previous studies used non-specific and indirect outcomes like changes in larval indices of *Aedes*. Variations in the mode of interventions, high risk of bias, methodological heterogeneity, statistical heterogeneity and presence of co-interventions were the limitations. Very few studies reported disease-specific outcomes, which might have reduced the power of the analysis. Only subgroup analysis was used to explain heterogeneity. We used only controlled trials with specific outcomes for the current analysis. It ensured the quality of input data and made the pooling of data easier. However, such an approach is prone to selection bias as most of the studies in the literature are field trials without a control group and observational studies using a multitude of outcome variables. Recent publications might also have been missed because the time frame of the literature search was through 2022. The *A. aegypti* abundance indicators were the common outcome measures cited in most of the studies included in the review. Hence this review could not specifically investigate the effects of anti-adult interventions on *A. albopictus*. Our literature research did not yield studies from India or Africa, which might impact the generalizability of the review findings.

### Conclusions and recommendations

The current scoping review and meta-analysis appraised the effectiveness of interventions targeting *Aedes* adults in reducing the burden of *Aedes*-borne diseases. It concluded that such interventions will significantly reduce the number of indoor adult *A. aegypti* mosquitoes, which are instrumental in the spread of *Aedes*-borne infections. Sensitivity analysis showed that there is a significant reduction in the number of indoor adult mosquitoes irrespective of the type of intervention. There was a marked reduction in the incidence of dengue in houses that deployed the measures against adult *Aedes* mosquitoes, but the effect size was not statistically significant. The reduction in the incidence of dengue as measured by the change in seroprevalence became more marked when the studies with more risk of bias were removed from the model. Thus we advocate for more robust field trials, keeping valid measures for reducing *Aedes*-borne infection



as the outcomes. This meta-analysis also noted that there is a paucity of trials from high-priority areas like India and Africa.

## Supplementary data

Supplementary data are available at *Transactions* online.

**Authors' contributions:** TSA and RKP were responsible for the conceptualization of the study. TSA, PSI and RKP prepared the initial proposal. All authors approved the proposal. TSA and JV were responsible for the preliminary search and screening of titles and abstracts. For full-text review, TSA was the first reviewer, PSI was the second reviewer and RKP was the third reviewer. Data extraction and synthesis were done by TSA. It was reviewed and finalised by SP and ZTN. TSA, PSI and RKP wrote the manuscript and all authors approved the final version of the article. ZTN and SP provided inputs throughout the process.

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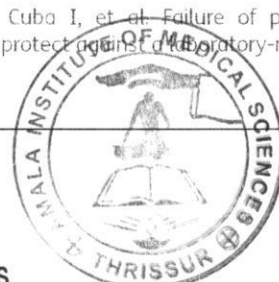
**Data availability:** The data underlying this article are available in the article and its online supplementary material.

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