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Integrated malaria prevention in low- and middle-income countries: a systematic review

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Abstract

Background As many countries aim to eliminate malaria, use of comprehensive approaches targeting the mosquito vector and environment are needed. Integrated malaria prevention advocates the use of several malaria prevention measures holistically at households and in the community. The aim of this systematic review was to collate and summarize the impact of integrated malaria prevention in low- and middle-income countries on malaria burden.

Methods Literature on integrated malaria prevention, defined as the use of two or more malaria prevention methods holistically, was searched from 1st January 2001 to 31st July 2021. The primary outcome variables were malaria incidence and prevalence, while the secondary outcome measures were human biting and entomological inoculation rates, and mosquito mortality.

Results A total of 10,931 studies were identified by the search strategy. After screening, 57 articles were included in the review. Studies included cluster randomized controlled trials, longitudinal studies, programme evaluations, experimental hut/houses, and field trials. Various interventions were used, mainly combinations of two or three malaria prevention methods including insecticide-treated nets (ITNs), indoor residual spraying (IRS), topical repellents, insecticide sprays, microbial larvicides, and house improvements including screening, insecticide-treated wall hangings, and screening of eaves. The most common methods used in integrated malaria prevention were ITNs and IRS, followed by ITNs and topical repellents. There was reduced incidence and prevalence of malaria when multiple malaria prevention methods were used compared to single methods. Mosquito human biting and entomological inoculation rates were significantly reduced, and mosquito mortality increased in use of multiple methods compared to single interventions. However, a few studies showed mixed results or no benefits of using multiple methods to prevent malaria.

Conclusion Use of multiple malaria prevention methods was effective in reducing malaria infection and mosquito density in comparison with single methods. Results from this systematic review can be used to inform future research, practice, policy and programming for malaria control in endemic countries.

Keywords Integrated approach, Malaria prevention, Multiple methods, Low- and middle-income countries

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Background

In 2020, there was an estimated 241 million cases of malaria, and 627,000 deaths from the disease globally [1]. Africa is the continent with the highest burden of malaria, accounting for 95% of all malaria cases and deaths, with children under 5 years of age and pregnant women being most vulnerable [1]. Estimates of the true burden of malaria in low-and middle-income countries (LMICs) including in Africa have been difficult to obtain due to underreporting of malaria cases and deaths [2]. The current malaria burden could thus be much higher than the estimates suggest. In addition to its impact on morbidity and mortality, the occurrence of malaria results in vast social and economic consequences. The economic costs are directly related to seeking treatment or preventive measures, or indirectly related to low productivity due to absenteeism from school or work, and time lost caring for the sick [3, 4].

Globally, malaria prevention has mainly relied on mosquito vector control by using insecticide-treated nets (ITNs), particularly long-lasting insecticidal nets (LLINs), and indoor residual spraying (IRS) [1]. In many malaria endemic countries, a vast effort has been made by ministries of health and their partners to increase coverage and utilization of ITNs and IRS. These efforts include the provision of LLINs and IRS to most at risk populations, although universal coverage for these interventions has not been achieved [5]. However, global malaria burden has not decreased significantly in recent years despite the efforts of increasing ITN and IRS coverage [1, 6]. Countries that have recorded significant gains in malaria control, such as El Savador which was certified by the World Health Organization (WHO) in 2021 as malaria free have used comprehensive approaches [1]. Although global and national malaria vector control efforts have predominantly focused on ITNs and IRS, several other control strategies can be implemented at household level to reduce mosquito density. These control measures include improving housing quality to limit mosquito entry, larval source management, and minimizing the presence of mosquitoes in houses for example by using insecticide sprays [7].

The use of appropriate combinations of non-chemical and chemical methods of malaria vector control in the context of integrated vector management has been recommended by the WHO [8]. Indeed, a combination of malaria prevention strategies has been shown to have greater impact than single methods [9–11]. Integrated malaria prevention therefore is an innovative approach that advocates the use of several malaria prevention measures in a holistic manner at household and community levels [12, 13]. These measures include proven malaria control methods and other approaches known to reduce mosquito populations. The specific methods advocated in the integrated approach are: (1). sleeping under LLINs; (2). installing screening in windows, vents and open eaves to prevent mosquito entry into houses; (3). IRS; (4). improving housing structure to limit mosquito entry; (5). larval source management; 6). closing windows and doors at sunset to reduce mosquito entry into houses; (7). larviciding in large water pools of stagnant water; (8). topical and spatial mosquito repellents; (9). mosquito coils; (10). insecticide sprays [12]. Although these various methods to reduce mosquito populations and prevent malaria exist, it is not expected that all of them will be used in a household due to several reasons including high cost, labour intensity, and side effects related to those that are insecticide based.

There is increasing evidence on the benefits of using multiple malaria prevention methods in households and communities particularly ITNs and IRS in comparison with single methods [14]. However, several studies have employed other malaria prevention methods in the integrated approach such as improving housing quality [15] and larviciding in recent years [16] Despite this available literature, there is limited evidence synthesizing findings from studies that have used two or more malaria prevention methods holistically. In addition, it is important to establish which other malaria prevention measures beyond ITNs and IRS have been used, and their contribution to controlling the disease. The aim of this systematic review was therefore to collate and summarize the impact of integrated malaria prevention in low- and middle-income countries on malaria burden. The systematic review adds to the evidence on use of two or more malaria prevention methods beyond the commonly used ITNs and IRS in endemic countries.

Methods

PubMed, CINAHL, Web of Science, Embase, Cochrane library, Scopus, and The Malaria in Pregnancy Consortium Library, thesis online, Google Scholar, OpenGrey, ProQuest, ClinicalTrials.Gov, PACTR registry, and World Health Organization International Clinical trials registry platform were searched for literature from 1st January 2001 to 31st July 2021. Integrated malaria prevention was defined as the use of two or more malaria prevention methods holistically. The primary outcome variables were malaria incidence and prevalence, while the secondary outcome measures were human biting and entomological inoculation rates, and mosquito mortality. This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analysis Protocols Guidelines (PRISMA-P) [17]. The review protocol was registered in the International Prospective Register

have influenced the quality and extent of interventions used at various times and resultant findings.

Conclusions

Use of multiple malaria prevention methods was effective in reducing malaria incidence, prevalence, human biting and entomological inoculation rates, as well as increasing mosquito deterrence and mortality in comparison with single methods. However, a few studies showed mixed results or no benefits on using multiple approaches to prevent malaria. More evidence is needed on the effectiveness of some malaria prevention methods for malaria control used individually or in combination. Results from this systematic review could inform future research, as well as practice, policy and programming on integrated malaria prevention in endemic countries to add to existing national and global control efforts.

Abbreviations

Bti	*Bacillus thuringiensis* Var israelensis
DEET	N,N-Diethyl-meta-toluamide
EIRs	Entomological inoculation rates
HBRs	Human biting rates
IRS	Indoor residual spraying
ITNs	Insecticide-treated mosquito nets
LLINs	Long-lasting insecticidal nets
LMIC	Low- and middle-income country
LSM	Larval source management
PBO	Piperonyl butoxide
RCT	Randomized controlled trial
WHO	World Health Organization
WSEBs	Window screens and eave baffles

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Author contributions

DM conceived of the study. EA conducted the initial review with the support of CN, RN and DM. RKW and MRK provided mentorship during the course of the study and were involved in writing the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study are from different sources (PubMed, CINAHL, Web of Science, Embase, Cochrane library, Scopus, and The Malaria in Pregnancy Consortium Library, thesis online, Google Scholar, OpenGrey, ProQuest, ClinicalTrials.Gov, PACTR registry, and World Health Organization International Clinical trials registry platform) and are included in the list of references.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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