Do Mosquito Coils Prevent Malaria? A Systematic Review of Trials

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Background: Official guidelines commonly advise travelers to burn mosquito coils as one means of preventing malaria. The objective of this study was to discover if insecticide-containing mosquito coils (1) prevent mosquito bites and therefore malaria acquisition, and (2) are safe in terms of their adverse effects on human users.

Methods: We sought published and unpublished controlled trials in this area, by (1) contacting experts, (2) searching the Cochrane Library, (3) interrogating bibliographic databases, (4) Internet search, (5) citation scanning, (6) scanning conference proceedings, and (7) writing to manufacturers.

Results: Fifteen controlled trials of insecticide-containing mosquito coils met our predefined inclusion criteria. We found no controlled trials measuring the incidence of clinical malaria as an outcome. Studies tested the efficacy of coils in achieving mosquito bite reduction (reported in 14 studies), mosquito repellence (seven), deterrence (five), "knockdown" effect (five), and percentage mosquito mortality (seven). Of the 38 separate outcome measures reported, antimosquito efficacy was reported as positive for $>95\%$. One trial reported no antimosquito effect at all, for one outcome only. Some insecticide classes and strengths were associated with better antimosquito outcomes than others. One trial identified possible adverse effects (irritation of the eyes and nose) in human users of this technology.

Conclusions: There is no evidence that burning insecticide-containing mosquito coils prevents malaria acquisition. A randomized field trial should be conducted, with malaria incidence as a primary outcome. There is consistent evidence that burning coils inhibits nuisance biting by various mosquito species. The potential harmful effects of coil smoke on human users should be investigated.

Malaria is the most important parasitic disease of humans, infecting around 5% of the world's population, and causing approximately one million deaths each year.[1] The disease is strongly resurgent, due to the effects of war, climate change, increased population movement, drug and insecticide resistance, and neglect of public health infrastructure.[2] Malaria is currently endemic in over 100 countries, which are visited by over 125 million international travelers every year.[3]

Humans acquire malaria from sporozoites transmitted by the bite of infected anopheline mosquitoes.[4] Most malaria-carrying mosquitoes hunt and feed at night.[5] Worldwide, there are about 400 mosquito species in the *Anopheles* genus, and, of these, around 80 species are known to transmit malaria, with 27 considered to be efficient vectors of the disease.[6] Malaria can develop after just one infective bite from an anopheline mosquito.[7] There is currently no effective vaccine against malaria.[8]

Official guidelines on malaria prevention often recommend burning mosquito coils as an effective means to prevent this disease.[3,9,10] Electrically heated vaporizing mats are also commonly recommended.

Mosquito coils are made from a paste of powdered insecticide and a filler such as sawdust, which is extruded into a spiral shape. The coil is mounted on a metal stand, and the free end of the spiral is lit (fig.). Once alight, the coil will smoulder at a steady rate for 6 to 8 h, releasing smoke that acts as a carrier to distribute the insecticide throughout the room.

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Figure A mosquito coil in use.

Coils thus function as fumigants, and achieve their effect by killing resting mosquitoes and preventing them from feeding overnight. For maximal effectiveness, rooms should be closed to ensure saturation of all mosquito resting areas. A common strategy is to ignite the coil, leave the room, and return in 1 to 2 h.[11]

Coils may differ markedly in their active components. Whereas some contain allethrin or another pyrethroid, others may contain DDT (generally considered to be less effective) or lindane.[12] This leads to different toxicities and efficacies, depending on the product.[13]

Compared to malaria chemoprophylaxis, mosquito coils are inexpensive and are advertised on many websites for approximately $2.50 per packet of 10. In poor countries they may be purchased locally for about one-tenth of this price. Coils are readily portable, and may appeal to some travelers who do not wish to take antimalaria drugs.

There is some awareness among travel medicine advisors that the particles and gases generated through burning mosquito coils may affect "persons with breathing problems",[11] or may cause "possible airway irritation",[12] but beyond that, little is known of their potential harmful effects on human users.

Our objectives in carrying out this systematic review of published and unpublished controlled trials were twofold: first, to discover if burning insecticide-containing mosquito coils prevents mosquito bites, and therefore malaria acquisition; and second, to establish if burning mosquito coils is safe, in terms of the possible adverse effects on humans of coil smoke and particles.

Methods

We sought controlled trials of insecticide-containing mosquito coils, through a combined approach based on the methodology of the Cochrane Collaboration.[14]

First, we wrote to national and international experts in this field, asking them for details of any controlled trials of mosquito coils which they had participated in, or had seen reported, or had heard about.

We searched the Cochrane Central Register of Controlled Trials, which contains abstracted information on 375,143 published trials.[14]

We interrogated the bibliographic databases MEDLINE, EMBASE, LILACS and CINAHL, using various combinations of search terms and key words, including "malaria", "malaria protection", "malaria prevention", "mosquito coils", "mosquito repellents", "pyrethrum", "pyrethrin" and "pyrethroid".

We performed a series of Internet searches (last search: 30 April 2003), using the commercial search engines Google (www.google.co.uk) and Ask Jeeves (www.ask.co.uk).

We reviewed abstracts of conference proceedings, and carried out citation scanning of standard textbooks and retrieved studies, again searching for references to controlled trials.

Finally, we wrote to manufacturers of mosquito coils.

Although we would ideally have carried out a manual search of one or more specialist entomology journals, looking for published but nonindexed controlled trials of mosquito coils, resources did not permit this. We were nevertheless able to perform a study-by-study search of a specialist CD-ROM, Pyrethrum Post, and this exercise yielded many relevant trials.

In summary, we sought published and unpublished controlled trials, in all languages, and without any time restrictions. We were confident that we had made all reasonable efforts to access the "gray literature" (namely, unpublished studies, conference abstracts and the like), and to avoid both publication bias and English-language bias.

Results

Effects of Coil Smoke on Mosquitoes

Fifteen controlled trials of mosquito coils, reported between 1967 and 1998 (Table 1), met our predefined inclusion criteria.[15–29] One of the trial reports was in French, and the remainder were in English.

Of the 15 trials we identified, 12 tested the efficacy of mosquito coils against anopheline mosquitoes, and 11 did so in a field setting.

Across the 15 trials, five separate study outcomes were reported (Table 2). These outcomes were mosquito bite

Table 1 Controlled Trials Identified[15–29]

Study Identifier	*Study Setting*	*Control Arm*	*Mosquito Species Tested*
Smith and Obudho (1967)	Field study	No intervention	*Anopheles gambiae*
Fales et al (1968)	Laboratory study	Blank coils	*Culex pipiens*
Chadwick (1970)	Laboratory study	No intervention	*Ae. aegypti*
Hudson and Esozed (1971)	Field study	No intervention	*Anopheles gambiae*, *Mansonia uniformis*
Smith et al (1972)	Field study	No intervention	*Anopheles gambiae*, *Culex fatigans*, *M. uniformis*
Smith et al (1973)	Field study	No intervention	*Anopheles gambiae*, *Culex fatigans*, *M. uniformis*
Chadwick (1975)	Laboratory study	No intervention	*Ae. aegypti*, *Anopheles stephensi*, *Culex pipiens fatigans*
Lubega et al (1977)	Field study	No intervention	*Anopheles gambiae*, *Culex fatigans*, *M. uniformis*
Charlwood and Jolley (1984)	Field study	No intervention	*Anopheles faruti*, *Anopheles koliensis*, *Anopheles punctulatus*
Birley et al (1987)	Mixed field / laboratory study	Blank coils	*Ae. aegypti*, *Anopheles gambiae*
Coene et al (1989)	Field study	No intervention	*Anopheles gambiae*, *Culex fatigans*
Yap et al (1990)	Field study	No intervention	*Culex quinquefasciatus*
Manga et al (1995)	Field study	No intervention	*Anopheles funestus*, *Anopheles gambiae*, *Anopheles moucheti*, *Anopheles nili*, *Anopheles paludis*
Hewitt et al (1996)	Field study	No intervention	Mixed species—anophelines and culicines
Lukwa and Chandiwana (1998)	Field study	No intervention	*Anopheles gambiae*

Table 2 Antimosquito Outcomes Tested[15–29]

Study Identifier	*Bite Inhibition*	*Repellence*	*Deterrence*	*"Knockdown"*	*% mortality*
Smith and Obudho (1967)	✓	✓	✓	–	✓
Fales et al (1968)	–	✓	–	✓	✓
Chadwick (1970)	✓	–	–	✓	–
Hudson and Esozed (1971)	✓	✓	–	–	–
Smith et al (1972)	✓	✓	✓	–	✓
Smith et al (1973)	✓	✓	✓		✓
Chadwick (1975)	✓	–	–	✓	✓
Lubega et al (1977)	✓	✓	✓	–	✓
Charlwood and Jolley (1984)	✓	–	✓	–	–
Birley et al (1987)	✓	–	–	✓	–
Coene et al (1989)	–	–	–	–	–
Yap et al (1990)	✓	–	–	–	–
Manga et al (1995)	✓	✓	–	–	–
Hewitt et al (1996)	✓	–	–	–	–
Lukwa and Chandiwana (1998)	✓	–	–	✓	✓

✓ = outcome reported as positive; – = outcome not reported (or reported as negative)

reduction (tested in 14 trials), mosquito repellence (tested in seven), deterrence (tested in five), "knockdown" effect (tested in five), and percentage mosquito mortality (tested in seven). Of the 38 separate outcomes reported, antimosquito efficacy was reported as positive for > 95%. Except in the case of mosquito mortality, a higher strength of the active insecticide component generally resulted in greater antimosquito efficacy. Only one trial reported no antimosquito effect at all, for one outcome only; the active component of the coil used in this trial in Zaire was 5% DDT.[25]

We found no trials of mosquito coils which measured the incidence of clinical malaria as an outcome.

Generally, therefore, it may be said that burning insecticide-containing mosquito coils inhibits nuisance biting by various mosquito species.

Effects of Coil Smoke on Humans

Just one trial reported irritation of the eyes and nose "similar to hay fever" after exposure to burning coils containing pyrethrins.[18] The authors, however, did not investigate the natural history of these harmful effects (e.g., through a cohort study), and nor did they explore their etiology (e.g., through a nested case-control study).

Discussion

Systematic Reviews

Systematic reviews are regarded as the best methods to summarize evidence on the effectiveness of health care interventions. They are designed to avoid biases and make results and conclusions as objective as possible.[30]

Systematic reviews are often used to determine if scientific findings are consistent across different studies, and whether or not those findings can be generalized to whole populations.[31,32]

Systematic reviews also highlight any inconsistencies and conflicts in the primary research evidence, and in this way can help to identify whether or not a health care intervention could be effective in one setting but be of no value in another.[32]

In many systematic reviews, meta-analytic methods are used to pool quantitative outcomes and to provide more precise measures of effect.[30] However, this was not possible within this systematic review, owing to the extreme heterogeneity of the 15 trials we identified. Eleven of the 15 identified trials were field studies, three were laboratory studies, and one was a mixed field/laboratory study (Table 1). Different classes of insecticides, at different strengths, were used across studies and also within studies. Coils were lit at different times of the evening or night, and were allowed to burn for different durations. Results were reported inconsistently across studies, and authors sometimes appeared not to have a clear understanding of certain key entomologic concepts (e.g., using "repellence" interchangeably with "deterrence").

Is There a Place for Mosquito Coils?

There exists only very limited observational evidence that burning mosquito coils has any useful part to play in malaria prevention. During a 6-month multinational military deployment to East Timor, 640 Italian troops used mosquito coils containing 0.2% to 0.3% pyrethrin in addition to bed nets, permethrin-impregnated uniforms, skin-applied repellents and chemoprophylaxis; they had no cases of malaria. By contrast, 360 British and 5,500 Australian troops, who deployed for the same period, used the same antimalaria technologies as the Italian force, with the exception of mosquito coils; they reported nine and 276 cases of malaria, respectively.[33] Owing to the many biases in this nonrandomized study, however, a protective antimalaria benefit from mosquito coils could not be inferred.

The results of this systematic review show that, in general, the insecticidal vapor released in the smoke of a burning mosquito coil is effective in reducing the number of biting mosquitoes, or at least the number of mosquito bites received by a host in the immediate vicinity of a burning coil. It is difficult, however, to quantify precisely how effective coils are in terms of the five discrete antimosquito properties of coil smoke (bite reduction, repellence, deterrence, "knockdown" and death). This is because the bite reduction reported in the majority of trials could have been caused by more than one of these modes of action. For example, a combination of direct bite inhibition (where the insecticide vapor interferes with the mosquito's normal host-finding mechanisms), repellence and deterrence may work additively or synergistically to prevent a mosquito from locating a suitable host.

Since none of the 15 trials measured clinical malaria as an outcome, it cannot be inferred that mosquito coils reduce malaria transmission. Intuitively, a reduction in the number of mosquito bites would seem likely to lower the potential for vector-borne disease. However, since just one infective anopheline bite is needed to transmit malaria,[7] a modest reduction in bite numbers could very well have no clinical impact at all.

The findings of this systematic review suggest that coils might be useful in protecting against other mosquito-borne diseases such as dengue fever and yellow fever, both transmitted by mosquitoes of the *Aedes* genus. As with malaria, however, this is an untested hypothesis, and is not supported by any measured clinical outcomes.

Conclusions

There is no evidence that burning insecticide-containing mosquito coils prevents malaria acquisition.

The 15 controlled trials identified in this systematic review provide consistent evidence that coils inhibit nuisance mosquito biting. Different insecticide classes, and different strengths of the same insecticide, are associated with better antimosquito outcomes. There is a clear need for standardization and quality control in the manufacture and sale of mosquito coils.[25]

The research question posed by this systematic review has highlighted a number of gaps in the malaria prevention knowledge base. These gaps need to be filled by focused, coordinated experimental research.

First, at least one randomized field trial needs to be conducted, with clinical malaria as an outcome, to determine if coils can reduce malaria transmission by locally reducing the numbers of biting anopheline mosquitoes, or the number of mosquito bites.

In addition, there is scope for a large randomized trial to be performed to test each of the five known antimosquito properties of coils, against a broad range of wild anopheline species, and using a variety of insecticide classes and strengths.

Finally, a rigorous safety study is needed to determine whether or not the prolonged use of mosquito coils has harmful effects on human users.

In a forthcoming systematic review we will investigate whether vaporizing mats prevent malaria.

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