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EVALUATION OF LAMBDACYHALOTHRIN-IMPREGNATED BEDNETS IN A MALARIA ENDEMIC AREA OF INDIA. PART 1. IMPLEMENTATION AND ACCEPTABILITY OF THE TRIAL

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ABSTRACT. In malaria endemic forested villages in Orissa State, India, a 3-year comparison of nylon nets treated with lambdacyhalothrin at 25 mg/m², untreated nets, and no nets was carried out. Treated nets retained high insecticidal efficacy for more than 7 months. Nets washed after 3 months of use gave 98% kill in a bioassay with a 3-min exposure. Based on these bioassays during the first year, nets were later reimpregnated at 6-monthly intervals with participation of the users. Compliance with the use of nets was good. Eighty-eight percent of nets were usable even after 3 years. The main benefits perceived by treated net users were reductions in malaria, mosquito bites, head louse infestations, and other nuisance insects. The trial was well accepted by the community. Issues related to social marketing and promotion of nets are discussed.

KEY WORDS Malaria, bednets, lambdacyhalothrin, India, bioassays, compliance, community participation

INTRODUCTION

Despite an organized malaria eradication program a resurgence of malaria occurred in India in the early 1970s, with the reasons being well documented (Sharma and Mehrotra 1986). A modified plan of operation decreased the incidence of malaria considerably and currently about 3 million malaria cases are reported annually in India (population > 950 million), one third of which are due to *Plasmodium falciparum*. Perennially the worst-affected areas are the forested hills inhabited mostly by aboriginal tribes. In Orissa State in eastern India, which is predominantly inhabited by tribal people, malaria is a serious public health problem accounting for about one third of all *P. falciparum* cases and one half of the number of malaria deaths in India (Yadav 1991). In the forested hills malaria transmission is high and is supported by several species of vectors (Yadav and Ghosh 1991). Most malaria morbidity is due to *P. falciparum* (76.8%), followed by *Plasmodium vivax* (18.8%), *Plasmodium malariae* (1%), and mixed infections (3.4%) of these species (Yadav et al. 1990).

At present vector control is based on indoor residual spraying of DDT in the region, although the spray coverage is poor and the general opinion of the people is not in favor of DDT spraying. In recent years renewed interest has been generated in bioenvironmental methods of malaria control, especially the use of larvivorous fish and larvicidal bacteria, and elimination of breeding sites. However, in view of the limited scope of bioenvironmental control in the forested hills with extensive vector breeding habitats, appropriate supplementary measures or new alternatives are needed.

Among the well-known methods of personal protection, bednets (mosquito nets) have been in use for many years against mosquitoes and nuisance insects (Lindsay and Gibson 1988). However, mosquitoes could enter improperly hung or torn nets or bite body parts touching the net. Impregnation of bednets with synthetic pyrethroids has been found to be very effective against disease vectors (World Health Organization [WHO] 1989) and the global experience on using impregnated nets against malaria is positive (Curtis et al. 1990). Impregnated bednets substantially reduced child mortality in the Gambia (D'Alessandro et al. 1995), Ghana (Binka et al. 1996), and Kenya (Nevill et al. 1996). Studies in Asia also have reported good efficacy of treated nets (Luxemburger et al. 1994, Vythilingam et al. 1995, Rowland et al. 1997). In China alone up to 2.4 million nets owned by householders in Sichuan Province have been sprayed with deltamethrin against malaria (Cheng et al. 1995).

In India a study in Assam State in the late 1990s reported high efficacy of deltamethrin-treated nets (Jana-Kara et al. 1995). We therefore conducted an efficacy trial (1 year baseline and 3 years intervention) beginning in May 1989 on the use of lambdacyhalothrin-impregnated bednets compared with untreated nets or no nets in a malaria endemic area of Orissa State. In this paper we present the study design, implementation methodology, and acceptability of the trial, whereas the impact on vector populations and malaria morbidity are reported subsequently (Sampath et al. 1998, Yadav et al. 1998).

Trial area

The trial was conducted in the Kumjharia section of the Kuarmunda Primary Health Centre (PHC), district Sundargarh, about 30 km from the field station of the Malaria Research Centre in the city of Rourkela in Orissa State, eastern India. Four vil-

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lages (Kumjharia, Koinargarh, Patuabahal, and Jytiara; population 1,147, comprising 6 hamlets [tolas]) received treated nets, 5 villages (Lassey, Therlibahal, Bagiajore, Bijabahal, and Sagabeda; population 1,226, each consisting of one hamlet) received untreated nets, and 1 village (Dumangdiri; population 786, comprising 8 hamlets) without nets served as the control.

Villages were located among undulating forested hills. At least one of the hamlets of each village was connected by road to the PHC. Most villages did not have electricity. Sources of water were hand pumps, perennial streams, wells, and small ponds. Allocation of villages to different treatment groups was based on malaria endemicity, geographic location, and logistics, on the basis of baseline data for 1 year. Most houses had tiled roofs, mud-plastered walls, and verandas at the front. Walls and floors of the houses as well as floors of the courtyards were generally plastered with mud periodically.

Climate

The area has deciduous wet forest and tropical climate with high rainfall (1–1.5 m) and relative humidity (50–90%). Mean monthly temperature ranged from 19.3°C in January to a high of 36.7°C in May. Three seasons may be distinguished: hot dry (mid-February to mid-June), monsoon (mid-June to mid-October), and cool dry (mid-October to mid-February).

Population census and livestock

A population census was conducted in 1989 and updated every year. A surveillance card was fixed on each house, which the malaria surveillance worker initialed on each weekly home visit. Census data were analyzed on a microcomputer. The male to female ratio was 1,628 to 1,531. The average family size was 5.5. The main tribes were Munda, Oraon, Kharia, Bhuiyan, and Kisan. Major occupations were agriculture, including collection of forest products (60%); laboring (13%); employment in government or private jobs (7%); and animal grazing (4%). More males (43%) than females (23%) were literate and <2% of the population were university graduates. The numbers of livestock and poultry were the following: 2,509 cattle, 1,597 goats and sheep, 171 pigs, and 2,826 poultry.

Bednet impregnation and distribution

Before the project started, bednets were rarely (<1%) used in the villages. Therefore, nylon bed nets of 2.5-mm mesh with 10-cm cotton hems were purchased in bulk (single net, 50 rupees or U.S. $2.70; double net, 75 rupees or U.S. $4.10; 1989 prices). The nets were impregnated with lambdacyhalothrin 5% emulsifiable concentrate (EC) at a dose of 25 mg active ingredient (AI)/m^2. The concentrate was mixed with the required amount of cold water in a plastic tub and impregnation was done by project staff wearing rubber gloves one net at a time by gently soaking and kneading the net with the emulsion. Nets were dried flat on plastic sheets for some time and hung in the shade to finish drying.

In May 1990 treated and untreated nets were distributed free of charge in the villages according to the actual requirement determined by baseline census surveys so that everyone had access to a net. The people were asked not to wash their nets until asked to do so when reimpregnation was due. Group meetings were organized in the villages to teach the people about the causes of malaria, the role of mosquitoes, different methods of hanging nets (for sleeping on cot-beds or on mats on the floor), and proper upkeep of nets. Help was given by school teachers, religious heads, and village headmen in ensuring better compliance with bednet usage. At a later stage village health committees were constituted involving local people to help supervise proper usage of bednets. Messages were also painted on walls.

Bioassays

To evaluate the persistence of residual efficacy of the pyrethroid-treated nets, bioassays were carried out periodically on bloodfed *Anopheles culicifacies* Giles malaria vectors collected from the control village. Batches of mosquitoes (3–5 replicates) were exposed for 3 min to treated net pieces (15 cm × 12 cm attached to a piece of paper) in WHO susceptibility test kits in the insectary; untreated net pieces served as controls. Knockdown of mosquitoes was recorded after 1 h and mortality was recorded after 24 h. Mosquitoes were also similarly exposed to pieces of nets washed once either after day 1 or after 3 or 6 months of regular use to determine the wash fastness of the pyrethroid. For washing, nets were rubbed in cold water with a locally popular detergent powder for 2–3 min, rinsed carefully, and dried in the shade.

Bioassay results (Table 1) showed nearly 100% mortality on unwashed nets up to 7 months after impregnation; these results are in agreement with those of Njunwa et al. (1991) who used 10 and 30 mg lambdacyhalothrin/m^2. In contrast, lambdacyhalothrin at 10 mg/m^2 gave much poorer persistence on polyethylene nets (about 85–100% mortality for 4–5 months, which reduced to 50% during months 6–8) but a prolonged persistence (85–100% up to 15 months later and 50% until 2 years posttreatment) on polyester nets at the same treatment (Curtis et al. 1996).

Nets washed after 3 months of regular usage caused 98.3% mortality, and those washed after 6 months caused about 42% mortality. In a contemporary study in India Das et al. (1993) also reported

Table 1. Results of bioassays of impregnated netting with *Anopheles culicifacies*.

Months after impregnation	Number exposed	% knockdown (1 h)	% mortality (24 h)
Bioassays of unwashed nets			
0	75	100.0	100.0
1	75	100.0	100.0
2	75	100.0	100.0
3	75	97.3	100.0
4	60	91.7	100.0
5	45	93.3	100.0
6	60	95.0	98.3
7	60	91.7	100.0
8	45	80.0	91.1
9	60	83.3	86.6
10	60	76.7	90.0
11	60	70.0	83.3
12	60	71.7	78.3
Bioassays after washing			
0	45	100.0	100.0
1	45	95.6	100.0
3	60	90.0	98.3
6	60	21.7	41.7

100% mortality for 6 months with unwashed nets and for more than 4 months after single washing.

Reimpregnation of bednets

Treated nets were reimpregnated after 1 year of use (i.e., in June 1991) and based on the results of bioassays during the first year, subsequent impregnations were made every 6 months. The users were asked to wash their nets thoroughly with their usual detergent or soap, dry them, mend tears, and bring them to a central place in each village on a fixed day. The nets were given numbers with indelible ink and were impregnated one by one because people did not like their nets to be impregnated with those of others. Impregnators were hired from the local villages. For drying by the respective owners the nets were laid on beds, bed clothes, or palm-leaf mats in huts or occasionally on a fence in the shade.

During the 3rd impregnation, in January 1992, the users were encouraged to participate actively. For subsequent impregnations, in June 1992 and January 1993, nets were treated by the users themselves. A project staff member prepared the emulsion in bulk and provided the required quantity for each net in a plastic tub. Members of each family impregnated their nets wearing rubber gloves and dried them as described earlier.

Sleeping habits and compliance with bednet usage

With the help of a team of local residents, surveys were carried out during the night after 2200 h in May 1991 (hot dry season) and November 1991 and December 1992 (cool dry season) to find out the general sleeping pattern of the population in different seasons. For analysis, data for all villages were pooled. The November 1991 survey recorded that 47% (734/1,559) of people slept on beds and 53% slept on mats on the floor. The average number of beds per family was 2.8.

Table 2. Bednet usage based on night surveys from 2200 h on.

Surveys	Nets	People (%)[1] checked	Bed net users
Hot dry season (May 1991)	Treated	463 (39%)	23%
	Untreated	363 (27%)	31%
Cool dry season (Nov. 1991)	Treated	652 (55%)	61%
	Untreated	624 (47%)	60%
Cool dry season (Dec. 1992)	Treated	627 (51%)	73%
	Untreated	733 (52%)	77%

[1] Number and percentage of people checked from the total population.

During the hot dry season, 62% (660/1,062) people slept indoors (24% in rooms and 38% on verandas) and 33% slept outdoors in courtyards. At this time the rate of bednet usage in the villages with treated and untreated nets was 23% (107/463) and 31% (113/363), respectively (Table 2). However, because transmission of malaria remained low in the hot dry season, the low use rate of bednets was unlikely to lead to many malaria infections.

During the cool dry season 99.5% of people slept indoors (80% in rooms and 19.5% on verandas), whereas only 0.5% slept in courtyards. The November 1991 survey coincided well with a high density of *An. culicifacies* (Chand et al. 1993) and the main malaria transmission period in this area, when the need of bednets was likely to be greatest. The survey showed that in villages with treated nets 60% of people used them, whereas in those with untreated nets the use rate was 61%. Thus, the use rate in the cool dry season was substantially more than in the hot dry season and these results are in agreement with those of Das et al. (1993). A year later, in December 1992, the net usage rate had risen significantly in both treated net (73%; $\chi^2 = 20.26$, $P = 0.001$, df = 1) and untreated net (77%; $\chi^2 = 44.01$, $P < 0.001$, df = 1) villages. This was apparently due to health education and a realization by the people of the benefits of bednet usage.

Bednet hanging practices

During the November 1991 survey we also attempted to find out how people hang and arrange their nets on beds. Because the huts had low ceilings, 69.5% (536/771) of nets were suspended from the ceilings with string and 20.9% (161/771) were tied to nails fixed on walls using string. People who slept outdoors on beds (8.8%) tied their nets to the

Table 3. Physical condition of bednets after 2 and 3 years of regular use.

Condition	Surveys	
	June 1992 (2 years use)	June 1993 (3 years use)
No. physically checked	1,836	1,791
In good condition	72.3%	59.8%
Slightly damaged	20.3%	30.5%
Causes of damage		
Children's activity	7.4%	8.7%
Normal use	6.0%	11.6%
Rat gnawing	4.7%	6.9%
Lamp burns	1.2%	2.0%
Smoking burns	1.0%	1.3%
Severely damaged	3.5%[1]	8.3% (11.8%)
Causes of damage		
Children's activity	1.3%	2.0%
Rats/cattle	1.3%	3.1%
Normal wear and tear	0.7%	2.8%
Burnt/termite damage	0.2%	0.4%
Missing	3.9%[1]	1.4% (5.3%)
Reasons		
Taken by emigrant students/workmen	3.1%	0.9%
Given away	0.3%	0.3%
Taken on marriage	0.3%	0.2%
Burnt with deceased or stolen	0.2%	0

[1] Replaced with new nets (cumulative loss after 3 years).

tops of bamboo sticks attached to the bed legs and crossed to form an X shape at each end of the bed. During the daytime, nets were rolled up along the bamboo sticks and kept indoors.

Physical condition of nets

Surveys conducted on the durability of nets (Table 3) showed that in June 1992, after 2 years of use, 72.3% of the nets were in good condition, 20.3% of the nets were slightly damaged, 3.5% of the nets were severely damaged, and 3.9% were missing altogether (n = 1,836). The missing and severely damaged nets were replaced with new ones. After 3 years of use about 60% of bednets were in good condition, 31% were slightly damaged, 8% were severely damaged, and 1.4% were missing, including the nets replaced previously. Reasons for damage or loss were varied, as shown in Table 3. Taking into account the loss of more than 5% of the nets and 11.8% cumulative damage, it is evident that about 83% of the nets were usable after 3 years of regular use, which is encouraging from the point of view of the cost of intervention.

Community participation and acceptability

Before this project introduced bednets, <1% of people used such nets in the study area. Even so, a 1991 study in the region showed that 51–85% of schoolchildren and about 36% of adults were aware of the use of mosquito nets for personal protection against mosquitoes and malaria (Yadav et al. 1993). Because the nets were provided free of charge, people were expected to use them properly and regularly, mend tears, prevent misuse, participate in treatment of nets with insecticide, and cooperate with the malaria surveillance workers. Overall community participation was very encouraging. About 90% (832/928) of bednets were brought by the users for reimpregnation during June 1992, and 89% (801/904) were brought in January 1993. Men treated 28–36% of the nets, and women treated the remainder. This gender difference was primarily because males were mostly engaged in other work.

Social leaders and village health committees were activated in motivating the people. This led to an increase in rate of bednet usage and a decrease in loss of nets. In fact, lost nets that were taken out of the area were often replaced by the people themselves. The leaders and committees were also helpful in allaying fears of the people of a particular hamlet that the impregnated nets caused any adverse effects, such as sterility. In fact, people generally reciprocated with goodwill and reported that, in addition to decreasing malaria and mosquitoes, the numbers of head lice, houseflies, and other small insects had decreased. They even demonstrated dead mosquitoes and other insects on hanging nets. Many felt that nets provided protection from scorpion or snake bites. Although some people re-

ported adverse effects, such as nasal and eye irritation, these were transient. Njunwa et al. (1991) also reported sneezing with a 30 mg/m² dose, but found little effect with 10 mg/m².

Before we introduced these impregnated bed nets, the reasons for people not having nets were mainly poverty and nonavailability of nets in the weekly markets (haat) in the tribal villages. By the completion of this trial, however, enquiries came from neighboring villages of the area from people who wanted to know the source of the pyrethroid insecticide and the nets so that they could buy them. Thus, nonusage of bednets in the area was not entirely due to low income but partly to ignorance or nonavailability of nets in haats. Better awareness about mosquito nets in schoolchildren may further help in promoting bednet usage in the future.

A recent survey in the city of Rourkela and an adjoining area showed that 67% (335/500) of urban people, 61% (157/257) of periurban people, and 6% (62/1,029) of rural people living near Rourkela used mosquito nets (Yadav and Sharma 1994). Mosquito nets made of nylon and cotton netting and in different colors and sizes are readily available in Rourkela. There are shops where nets are made according to the customer's preference in the price range of 65 rupees (U.S. $2.10, 1994 prices) to 175 rupees per net.

To promote bednet usage against malaria, social marketing of nets and involvement of nongovernmental organizations are needed, and the malaria control program needs to develop strong components of information, education, and communication. Although a few recent studies such as in Afghan communities (Rowland et al. 1997) and in tribal communities in Orissa, India (Yadav and Sharma 1997) have attempted to study sustainability of bed net usage, further studies of sustainability issues and sales and distribution systems for nets and insecticides are needed.

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