Parasitol Res (2009) 105:641–645
DOI 10.1007/s00436-009-1433-x

ORIGINAL PAPER

Field trials on the efficacy of DEET-impregnated anklets, wristbands, shoulder, and pocket strips against mosquito vectors of disease

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Received: 27 November 2008 / Accepted: 24 March 2009 / Published online: 8 April 2009

Abstract A field trial was undertaken in order to determine the efficacy of DEET (*N*,*N*-diethyl-*m*-toluamide) impregnated anklets, wristbands, shoulder and pocket fabric strips against mosquito vectors of disease. The present study was conducted in the urban locality of Pondicherry, India. Human test subjects were exposed to natural populations of mosquitoes for a 12 h (18.00–06.00) night time period. The fabric strips (anklets, wristbands, shoulder, and pocket strips) were impregnated with DEET at two different concentrations of 1.5 mg/cm^2 and 2.0 mg/cm^2. The results clearly revealed that DEET-impregnated anklets, wristbands, shoulder and pocket fabric strips were found more effective against mosquitoes remarkably. The DEET-impregnated anklets, wristbands, shoulder and pocket fabric strips at a concentration of 2 mg/cm^2 provided 5 h complete protection against mosquitoes bites and the reduction of man-landing rate varied between 65.85 and 100%. However, DEET-impregnated fabric strips at a concentration of 1.5 mg/cm^2 provided 4 h complete protection against mosquito bites and the reduction of man-landing rate varied between 51.21 and 100%. The final results clearly demonstrate that repellent activity of DEET-impregnated anklets, wristbands, shoulder, and pocket strips were dose-dependent. Certainly, the DEET-impregnated fabric strips can be used as an effective potential personal protection measure in order to avoid those insects/mosquitoes that prefer to feed outdoors or those that feed in the early evening.

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Introduction

Insect-transmitted diseases impose an enormous burden on the world's population in terms of loss of life (millions of deaths per year) and morbidity. These diseases are also responsible for huge economic losses, both in terms of health-care costs and lost productivity, mostly in countries that can least afford them (Jacobs-Lorena and James 2002). Mosquitoes are the vectors for the dreadful diseases of mankind. Of all the insects that transmit diseases, mosquitoes represent the greatest menace. WHO has declared the mosquito "public enemy number one" because mosquitoes are responsible for the transmission of various dreadful diseases (WHO 1996).

One to two million deaths worldwide are reported annually due to malaria. Lymphatic filariasis affects at least 120 million people in 73 countries including India and in the remaining countries in Africa, Southeast Asia, and Pacific Islands. These diseases not only cause high levels of morbidity and mortality but also inflict great economic loss and social disruption on developing countries such as India, China, etc. (Hotez et al. 2004).

Repellents play an important role in protecting humans from the bites of insect pests. An effective and safe repellent will be useful in reducing human–vector contact

and thereby help in the interruption of vector-borne disease transmission (Kalyanasundaram and Mathew 2005). Protection against insect bites is best achieved by avoiding infested habitats, wearing protective clothing, and applying insect repellent (Curtis 1992; Fradin 2001).

DEET (*N*,*N*-diethyl-*m*-toluamide, also known as *N*,*N*-diethyl-3-methylbenzamide) is very effective and most widely used insect repellent (Koren et al. 2003). Although insecticide-treated bed nets protect against mosquitoes and malaria in many parts of the world, people may contract disease in the early evening before they retire to the confines of the net, since exposure to malaria vectors and nuisance mosquitoes starts in the early evening (Maxwell et al. 1998).

People who are living in the remote rural areas and poorer section of the society endlessly suffer from many vector-borne diseases, particularly malaria due to lack of simple and cheap methods of personal protection (Karunamoorthi et al. 2008). Thus, there is the need to find supplemental personal protective measures to avoid insect/mosquito nuisance and prevent the disease transmission. Therefore, the present investigation was an attempt to find a simple and cheap method of personal protection measure against insects/mosquitoes bites.

Objectives

The aim of the present study was to determine the efficacy of DEET-impregnated wristbands, anklets, shoulder, and pocket strips at two different concentrations of 1.5 mg/cm^2 and 2.0 mg/cm^2 against mosquito vectors of disease under the field conditions.

Materials and methods

Repellent and fabric strips

DEET 25% (E.C) was obtained from Division of insecticides-chemistry, Vector Control Research Center (VCRC), Pondicherry, India. The anklets, wristbands, shoulder, and pocket strips were made from terry-cotton (68:32) cloth. The cotton strips are about 10 cm wide and 35 cm long and elasticized so that they remain in place. The fabric strips (anklets, wristbands, shoulder, and pocket strips) were provided with Velcro strips at both ends in order to fasten.

Human volunteers

Selected three healthy male human test subjects were made in sitting position. Each volunteer was provided with a set of fabric strips in order to evaluate the efficacy of DEET-impregnated anklets, wristbands, shoulder, and pocket strips against mosquito vectors of disease. Informed and free consent were obtained from the volunteers.

Impregnation procedure

Initially, each of the fabric strips were soaked in water and the quantity of required DEET repellent to wet thoroughly the each of the fabric strips (anklets, wristbands, shoulder, and pocket strips) was measured. The quantity of water thus determined for each of the fabric strips was used to mix with the desired repellents at two different concentrations viz., 1.5 and 2 mg/cm^2. Methanol was used as a solvent to obtain the desired concentration of DEET repellent. The soaking of fabric strips was made in a non-absorbent plastic container. Uniform distribution of repellents was ensured by rubbing and squeezing of fabric strips. Subsequently, fabric strips were flattened on a polythene sheet for shade drying. After thorough drying, each set of fabric strips were kept in separate airtight plastic bags, in order to avoid the mixing with other concentrations.

Field evaluation method

The field study was carried out in an urban locality viz. Muthialpet in Pondicherry, India. This area is highly endemic for lymphatic filariasis due to *Wuchereria bancrofti* and the urban agglomeration continues to contribute vector mosquito *Culex quinquefasciatus.* The field trial was carried out by using healthy human male volunteers. The fabric strips (armbands, anklets, shoulder, and pocket strips) were impregnated with DEET at two different concentrations of 1.5 and 2.0 mg/cm^2.

Three volunteers were provided each with a set of wristbands, anklets, shoulder, and pocket strips. Two volunteers with DEET-impregnated fabric strips (anklets, wristbands, shoulder, and pocket strips), one volunteer was provided with a set of fabric strips at a concentration of 1.5 mg/cm^2, while another volunteer was provided with a set of fabric strips at a concentration of 2 mg/cm^2. Similarly, the control was set up by using a volunteer provided with a set of fabric strips treated with solvent (methanol). The mosquitoes landing on volunteer were collected by insect collectors at night (18.00–06.00). Informed and free consent were obtained from the volunteers for the present field trials.

The volunteers (human baits) were interchanged between the control and test at an interval of 30 min. Mosquitoes landing on treated and untreated volunteers were collected throughout the night with the help of a suction tube and a flash light by insect collectors. Insect collectors were rotated at an interval of 3 h to avoid bias collections. Mosquitoes collected every hour were kept separately, and then brought to the laboratory on the next day. Mosquitoes collected on baits were counted and identified in the

Table 1 Efficacy of DEET-impregnated fabric strips against vector mosquitoes, under the field conditions

S. No.	Period of observation	Control	No. mosquitoes collected 2mg/cm^2	% of Reduction of man-landing rate	No. mosquitoes collected 1.5mg/cm^2	% of Reduction of man-landing rate
1.	18–19	88	0	100	0	100
2.	19–20	110	0	100	0	100
3.	20–21	97	0	100	0	100
4.	21–22	139	0	100	0	100
5.	22–23	124	0	100	9	92.74
6.	23–00	185	12	93.51	19	89.72
7.	00–01	186	36	80.64	48	74.19
8.	01–02	138	32	76.81	44	68.11
9.	02–03	119	29	75.63	38	68.06
10.	03–04	94	28	70.12	32	65.95
11.	04–05	56	18	67.85	26	53.57
12.	05–06.	41	14	65.85	20	51.21

laboratory under a stereo-zoom microscope. Data analysis was carried out using SPSS, version 9.0. Range and mean were analyzed and appropriate tables, graphs, and percentage were displayed. Percent of protection from man–mosquito contact was calculated by the following formula (Sharma and Ansari 1994; Yap et al. 1998).

$$\% \text{ Protection} = \frac{C - T}{C} \times 100$$

Where,

C No. of mosquitoes collected from control group
T No. of mosquitoes collected from experimental group

Results

Field trial, using DEET-impregnated fabric strips for repellent activity

The results of complete protection time and percent of reduction of man-landing rates are presented in Table 1 and Fig.1. The DEET-impregnated anklets, wristbands, shoulder and pocket fabric strips at a concentration of 1.5 mg/cm^2 provided 4 h complete protection against mosquito bites and the reduction of man-landing rate varied between 51.21 and 100%. Besides, DEET-impregnated anklets, wristbands, shoulder and pocket fabric strips at a concentration of 2 mg/cm^2 provided 5 h complete protection against bites of mosquito vectors of disease and the reduction of man-landing rate varied between 65.85 and 100% (Table 1 and Fig. 1).

Mosquitoes landing on human volunteers, wearing the anklets, wristbands, shoulder and pocket fabric strips were impregnated with DEET 1.5 mg/cm^2 and 2.0 mg/cm^2 concentrations (treated) and were compared with control volunteers (untreated). During the first 2 h of observation (18.00–20.00), as many as 190 mosquitoes, belonging to three species *C. quinquefasciatus*, *Culex whitmorei*, and *Armigeres subalbatus*, were collected from the "control" volunteer, whereas no mosquito was found to have landed on the "test" volunteer, and hence, the later obtained 100% protection from mosquito biting at night (Table 1 and Fig. 1). In the next 2 h of observation, a marginal increase in mosquito density (236), with three more species

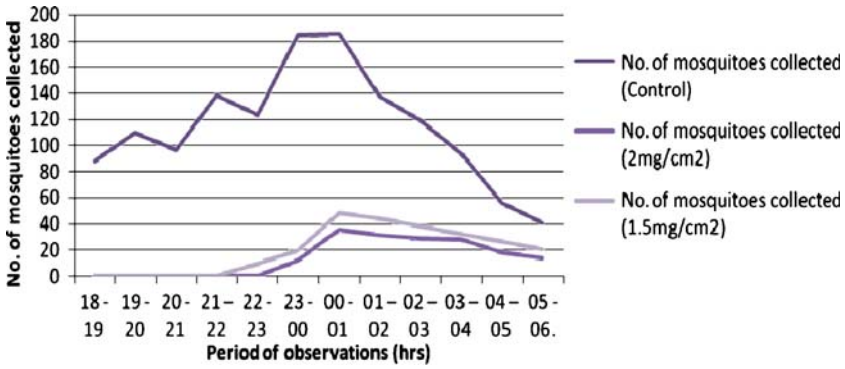

Fig. 1 Efficacy of DEET-impregnated fabric strips against vector mosquitoes under field conditions

(*Anopheles subpictus*, *Culex gelidus*, and *Culex vishnui*) was recorded on control volunteer. At the same time, 39 mosquitoes belonging to five species (*C. quinquefasciatus*, *C. whitmorei*, *C. vishnui*, *A. subpictus*, and *A. subalbatus*) were collected from the "test" volunteer (Table 1 and Fig. 1).

Discussion

DEET is an effective and well-known mosquito repellent, as testified by several decades of entomological research (McCabe et al. 1954; Schreck 1977; Curtis et al. 1990; Gupta and Rutledge 1994; Barnard 2000). The results of the present study are comparable with the following earlier reports. A study, carried out to determine the effect of impregnated cotton anklets with DEET, recorded 80–85% reduction in malaria mosquito biting on sitting probants in Tanzania (Curtis and Lines 1985). Similarly, the present study results revealed that human volunteers, wearing anklets, armbands, shoulder and pocket strips impregnated with DEET at two different concentrations viz., 1.5 and 2.0 mg/cm^2 under the field conditions. The concentration at 1.5 mg/cm^2 was found to be efficient and provided 4 h complete protection against mosquito bites, and reduction of man-landing rates varied between 51.21% and 100% (Table 1 and Fig. 1). A recent outbreak of malaria in a village in South Africa did subside after distribution of DEET repellent among the affected population (Durrheim and Govere 2002).

Studying the effectiveness of a net jacket treated with DEET in field against biting midges viz., *Culicoides furens*, *Culicoides hollensis*, and *Culicoides mississipiensis* has shown that it provided 98–99% protection, but against *Culicoides barbosai*, it provided only 59% protection (Schreck et al. 1979). Another study in the Vietnamese forest showed that mosquito bites on DEET users were reduced by more than threefold when sitting next to an unprotected partner who used a solvent control in comparison with the condition when treated volunteers sat alone (Nguyen et al. 2004). Likewise the DEET-impregnated strips at a concentration of 2 mg/cm^2 provided complete protection from mosquito bites for 5 h and the reduction of man-landing rate varied between 65.85% and 100% at different periods of observation during the night in the peridomestic situation (Table 1 and Fig. 1).

The field trials were conducted to evaluate the efficacy of commercial anti-mosquito products in Illinois. The results revealed that the DEET topical repellent had a consistently lower landing rate than all the non-topically applied products tested. However, the authors found that the mosquito coils and the DEET-impregnated wrist bands did significantly reduce mosquito landing rates relative to untreated controls (Jensen et al. 2000). A study was done to evaluate the personal protection afforded by uniforms treated with permethrin (0.125 mg/cm^2) against natural infestations of chigger mites, *Trombicula* spp. At the end of the 3-day period, there was a 74.2% increase in protection provided by the treated uniforms compared to an untreated uniform and the use of repellent (Breeden et al. 1982). These studies clearly indicated that DEET/permethrin-impregnated clothing can provide better protection against insects and mosquitoes bites. The present field trial results revealed that DEET-impregnated fabric strips can serve as a better personal protection measure (Table 1 and Fig. 1).

In addition, repellent bars (Mosbar^R), DEET-impregnated anklets and wristbands, have also been reported to confer good protection in the field (Chiang et al. 1990; Chiang and Eng 1991).

The final results of this present trial clearly demonstrate that repellent activity of DEET-impregnated wristbands, anklets, shoulder and pocket strips were dose-dependent and effective against insects/mosquitoes bites (Table 1 and Fig. 1).

Many species of bloodsucking insects bite predominantly around the ankles and wrists. Strips of cotton fitted around the extremities and impregnated with a repellent reduce insects/mosquitoes biting significantly. Impregnation of the repellent into cotton fabric strips is a more reasonable way for minimizing skin contact with DEET and they greatly reduce the man–vector contact. Furthermore, the DEET-impregnated fabric strips are extremely helpful and useful whenever and wherever other kinds of personal protection measures are impractical. In addition, they are much more economical and reimpregnation process is exceptionally simple as well as inexpensive.

Acknowledgment The authors sincerely thank (late) Dr. Vijai Dhande, the Director, Vector Control Research Centre, Pondicherry, India for approving this research work and the facilities provided to carry out this study. In addition, we are greatly indebted to Dr. M. Kalyanasundarm, Deputy Director, Vector Control Research Center, Pondicherry, India for his constant encouragement throughout the studies.

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