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Permethrin-impregnated bednets reduce nuisance arthropods in Gambian houses

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ABSTRACT. The prevalence of bedbugs (*Cimex hemipterus* L.), chicken ticks (*Argas persicus* Oken) and headlice (*Pediculus capitis* De Geer) was surveyed in a rural area of The Gambia. At the beginning of the study 37.5% of children's beds were infested with bedbugs and 3.9% with chicken ticks, whilst the prevalence rate of pediculosis in children under 10 years old was 28.8%. Both bedbugs and headlice were clustered within compounds. Headlice prevalence increased with hair length and they were more common on girls than boys.

Following this cross-sectional survey all bednets in the sixteen hamlets were either dipped in permethrin or a placebo. About 4 months later it was found that bedbugs and chicken ticks had disappeared from homes in which the bednets had been impregnated with permethrin. There was no reduction in hamlets with placebo-treated bednets. The rate of acquiring headlice between the two surveys was reduced by 91.1% in children who slept under insecticide-treated bednets compared with children with placebo-treated bednets. There were also significantly fewer day-flying and crawling insects, except earwigs, in homes of children who slept under insecticide-treated bednets compared with those with placebo-treated nets. These additional benefits of permethrin-treated bednets should contribute to their widespread acceptance and utilization by the community for personal protection.

Key words. *Argas persicus*, bedbugs, bednets, *Cimex hemipterus*, headlice, *Pediculus capitis*, permethrin, The Gambia, ticks.

Introduction

There is much interest in the use of insecticide-treated bednets as a way of controlling malaria (W.H.O., 1989). This strategy has resulted in a reduction in clinical malaria in children in Malaysia (Hi *et al.*, 1987), Mali (Ranque *et al.*, 1984), Papua New Guinea (Graves *et al.*, 1987) and, most successfully, in The Gambia (Snow *et al.*, 1987, 1988a).

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There have also been many accounts, mainly anecdotal, of insecticide-treated bednets killing nuisance arthropods such as bedbugs, cockroaches, headlice, houseflies or scabies mites (Charlwood & Graves, 1987; Lines *et al.*, 1987; Majori *et al.*, 1987; Snow *et al.*, 1987; Charlwood & Dagaro, 1989). In this paper we first describe the prevalence of the major nuisance arthropods in a rural area of The Gambia. We then report the impact of using permethrin-treated bednets against domiciliary arthropods of public health importance, excluding mosquitoes. The effect of this malaria control strategy on vector mosquitoes (Lindsay *et al.*, 1989) and the clinical consequences (Snow *et al.*, 1988a) are discussed elsewhere.

Methods

Study design. The study was carried out in sixteen Fula hamlets, near the town of Farafenni, in 1987. This area has been described previously by Greenwood *et al.* (1987), Snow *et al.* (1988a) and Lindsay *et al.* (1989). The people live in compounds with several houses belonging to one family, surrounded by a fence. The predominant ethnic group is Fula, with a few Mandinka and Wollof. All inhabitants of the hamlets were given bednets made of the synthetic nylon sheeting material most popular locally (Snow *et al.*, 1987). During the last 2 weeks of July 1987 all the bednets in seven of the settlements were treated with permethrin, a residual pyrethroid insecticide: in the other nine settlements nets were treated with a placebo, diluted milk (Snow *et al.*, 1988a). The procedure for impregnation of bednets was as described by Snow *et al.* (1988b). Briefly, the nets were dipped in a small vat of aqueous permethrin (diluted from 25% emulsifiable concentrate, 40:60 cis:trans, I.C.I.), wrung out and dried indoors, spread on top of the bed. The average concentration of insecticide on the netting was intended to be 500 mg a.i./m^2. Children 1–9 years old formed the study cohort.

Bedbug and tick surveys. Bedbugs were detected by visual searches of 360 children's beds in May 1987, 2 months before impregnation of the bednets, and again in November, nearly 4 months post-treatment. To reduce observer bias, surveys were carried out by fieldworkers who were told that all bednets had been treated with one of two insecticides and they were unaware of which hamlet received each treatment. As well as inspection of the bed-frame, linen and mattress (if present), the walls adjacent to the bed and the inside of the bednet were searched using a torch and a pair of forceps for 10 man-minutes. The efficiency of sampling was assessed after the second cross-sectional survey in November. A total of twenty beds previously judged as uninfested were randomly selected from the cohort of study children's beds; ten from each of the intervention and placebo groups. After dismantling the beds outdoors on a white sheet, each item was visually searched, sprayed with a non-residual synthetic pyrethroid insecticide (0.3% d-allethrin and 0.1% d-phenothrin: 'Target', Reckitt & Colman) and beaten to knock out any nymphs or adults onto the sheeting. Each search lasted 30 man-minutes.

Headlice surveys. Headlice were detected by a visual search of the scalps of 444 children in June, 1 month before dipping bednets, and at the end of November, 4 months post-treatment.

A fieldworker sat with a white cloth across her lap and held the child's head over it. She searched each scalp before and after combing, using a fine-toothed white comb. The comb and cloth were also inspected for the presence of nymphs, adults and their eggs. For children with much hair on their head, each inspection took approximately 10 min. Hair length was classified as shaved if the majority of the head was free of hair, short if the scalp had hair which could not hold a comb, and long if the hair could hold a comb or was braided.

Other insect surveys. Flying insects were

TABLE 1. Prevalence of bedbugs in all hamlets in May, at the end of the dry season, before treatment of bednets.

Strata	Children sleeping in infested beds	Prevalence rate
Sex		
Boys	94/232	40.5
Girls	70/182	38.5
Age (years)		
1–2	26/56	46.4
3–4	53/146	36.3
5–6	57/143	39.9
7–9	28/69	40.6
Ethnic group		
Fula	134/339	39.5
Mandinka	15/51	41.7
Wollof	15/24	62.5
Mean prevalence of children sleeping in infested beds/hamlet	46.4 (n=16, 95% C.I. 36.0–56.9)	
Mean prevalence of infested beds/hamlet	45.2 (n=16, 95% C.I. 35.2–55.2)	

collected by knockdown spray catches in sixty-two bedrooms of study children, 4 months after treatment of the bednets. This comprised one randomly selected room from every compound in each of the eleven hamlets in the west of the study area. Catches were carried out by covering the floor of the house with white sheets, spraying the room with 'Target' insecticide, leaving the house for 10 min, and then collecting insects knocked down onto the sheets. Spray collections were made at various times between 09.00 and 14.00 hours.

Crawling insects were captured using a non-toxic baited sticky trap (Trappit Lo-line Roach Trap, Biological Control Systems, Pontypridd) placed under the beds of all 187 children living in the western hamlets. Each trap was placed against the wall, under the middle of the bed, in October, 4 months after dipping the bednets, and collected 2 weeks later.

Results

Bedbugs

Before dipping the nets, 89.3% (360/403) of study children's beds were searched for bedbugs. Of the beds searched, 37.5% (135/360) were infested with eggs alone or all life-stages of the tropical bedbug, *Cimex hemipterus* L. Only 17.5% (63/360) of beds were infested with nymphs and adult bedbugs. Infestation was not significantly correlated with the sex or age of the child (Table 1). Wollofs had significantly more infested beds than did the Fulas and Mandinkas combined (χ^2=4.6, 1 d.f., P<0.05). Bedbugs were significantly clustered within compounds (z =13.15, P<0.001). This was demonstrated by comparing the observed number of compounds with no infested beds (66/107) with the expected number (24/107), assuming bedbugs were evenly distributed throughout the population (Smith & Pike, 1976).

Heavy infestations of bedbugs could be detected readily by the presence of life-stages, shed exoskeletons, bedbug faeces and the stains made by blood-fed bedbugs squashed inside the top corners of bednets. The commonest site for finding bedbugs using a visual search was in the mattress. These are typically made from jute sacking, filled with dry grass, and have a deep seam running around the edge where the bedbugs collect in the corners. However, more intensive searches, using an insecticide spray and beating with a stick, indicated that most of the bedbugs reside in the wooden bedframes.

TABLE 2. Prevalence of headlice in children, before dipping bednets, at the end of the dry season.

Strata	Children infested	Prevalence rates
Sex		
Boys	33/249	13.3
Girls	95/195	48.7
Age (years)		
1–2	6/53	11.3
3–4	33/159	20.8
5–6	48/152	31.6
7–9	41/80	51.3
Hair length*		
Shaved	3/141	2.1
Short	58/192	30.2
Long	60/106	56.6
Ethnic group		
Fula	107/372	28.8
Mandinka	13/50	26.0
Wollof	8/22	36.4
Mean prevalence of all children/ hamlet	33.8 (n=16, 95% C.I. 25.0–42.8)	
Mean prevalence, excluding shaved heads/hamlet	46.6 (n=16, 95% C.I. 35.8–57.4)	

*Hair length not recorded for five children.

In May, before bednets were treated in July there was a significantly higher prevalence of children sleeping in beds with nymph and adult bedbugs in the placebo group of hamlets than in the intervention group (Table 3, χ^2=8.80, d.f.=1, P<0.01). In the November post-treatment survey, however, no nymphs or adult bedbugs were found in any bed with permethrin-treated bednets (0/163), compared with 24.3% (44/178) infested beds in hamlets with placebo-treated bednets. The difference in the prevalence of bedbugs in beds before and after impregnating the nets with permethrin was very highly significant (χ^2=17.2, d.f.=1, P<0.001). Beds with bedbug eggs alone were not included in these calculations, since many may have been relics of past infestations, not markers of surviving colonies. Of 2×10 beds which were originally scored as being uninfested in the second survey, a longer and more intensive search showed that

TABLE 3. Prevalence of nuisance arthropods in houses before and after treating bednets with permethrin or a placebo.

Arthropod	Pre-treatment (dry season)		Post-treatment (wet season)		Percentage reduction in intervention group before and after treatment
	Placebo group	Intervention group	Placebo group	Intervention group	
Bedbugs*	43/179 (24.0)	20/182 (11.0)	44/178 (24.3)	0/163 (0.0)	100.0
Ticks*	7/179 (3.9)	7/181 (3.9)	9/178 (5.1)	0/163 (0.0)	100.0
Headlice†	78/242 (32.2)	50/202 (24.8)	67/223 (30.0)	10/189 (5.3)	78.6

Insect			No. insects/house		Percentage reduction in intervention group cf. control
			Placebo group	Intervention group	
Flying insects‡	–	–	88.4	12.0	86.4
Crawling insects‡	–	–	14.5	7.8	46.2

Number of infested * beds, † children and ‡ rooms.

two beds were infested. Both were from hamlets with placebo-treated bednets; two had bedbug eggs and one of these also had nymph and adult bedbugs.

Ticks

The soft tick *Argas persicus* Oken is an ectoparasite of chickens but will also feed readily on man. Chickens frequently roost under beds in houses in the study area. Ticks often lodge in small cracks in the wall alongside the bed, from where they emerge to feed on sleeping people. Although only 3.9% of children slept in a tick-infested bed, soft ticks were considered to be a particular nuisance by people unfortunate enough to sleep in these beds. Ticks were eradicated from households with permethrin-treated bednets but not from those with placebo-treated nets (Table 3). Comparing the prevalence of ticks in the intervention group before and after dipping the nets in permethrin showed that the reduction was significant (χ^2=6.4, d.f.=1, P<0.05).

Headlice

A total of 93.7% (444/474) of the study children were examined for headlice (*Pediculus capitis* De Geer) before treatment of bednets. The prevalence rate of head pediculosis in children was 28.8% (128/444). Headlice were more common in girls than boys and prevalence increased with hair length and age (Table 2). Girls had a significantly greater prevalence of headlice than boys, after adjusting for hair length using logistic regression analysis (Armitage & Berry, 1987). In addition, children with long hair had a greater prevalence of lice than children with short hair, after adjusting for the sex of the child. The increase in prevalence with age might be explained by the increase in hair length as the child gets older, or there might be a causal relationship. Headlice were significantly clustered within compounds (z =2.4, P<0.01). Fifty compounds had children with no headlice; the expected number if they were evenly distributed was forty-two.

There was no significant difference between headlice prevalence in each treatment group before dipping the bednets (Table 3, χ^2=2.65, 1 d.f., n.s.). Of those children with pediculosis before their bednets were treated, the reduction of headlice was 68.6% greater in children who slept under an insecticide-treated bednet compared with those using a placebo-treated bednet (χ^2=15.4, 1 d.f., P<0.001). For children originally without headlice, 91.1% more children had acquired infections by November if they slept under placebo-treated bednets instead of insecticide-treated bednets (χ^2=17.3, 1 d.f., P<0.001).

Other insects

All sixty-four rooms randomly selected for knockdown catches were sprayed successfully. On average, 7.4 times more flying insects were collected from houses with placebo-treated bednets compared with permethrin-treated bednets (95% CI for ratio of means=4.7–10.1, t=4.26, d.f.=9, P<0.01).

A total of 94.7% (177/187) of the sticky traps were recovered from under beds, 2 weeks after being set. From a survey of 100 sticky traps in placebo huts, the following numbers of crawling insects were recorded, mostly immature stages: 613 crickets (Orthoptera: Gryllidae), mostly *Gryllodes sigillatus* (Walker); 543 ants (Hymenoptera: Formicidae), mostly *Pachycondyla sennaarensis* (Mayr); 298 earwigs (Dermaptera); 126 cockroaches (Dictyoptera), mostly *Blattella* plus a few *Leucophaea*; 64 bristle tails (Thysanura). Excluding Dermaptera and one trap with 200 Hemiptera, there were 1.8 times more crawling insects in homes where bednets were treated with placebo compared with permethrin (95% CI for ratio of means=0.9–2.6, t=2.62, d.f.=10, P<0.05, Table 3). Surprisingly, there were 4.1 times as many earwigs (Dermaptera) in houses with permethrin-treated compared with placebo-treated bednets (95% CI for ratio of means=2.1–6.1, t=5.36, d.f.=10, P<0.001).

Discussion

The prevalence of bedbugs in bedrooms of the study hamlets was not significantly affected by the sex or age of children (Table 1). Although Wollofs had a greater prevalence of bedbug infestation than Fulas or Mandinkas, all the Wollofs in the study lived in one hamlet and are unlikely to be representative of this ethnic group. Bedbugs were clustered within compounds, suggesting that there may be familial factors – social, biological and/or environmenttal – which predispose individuals to bedbug infestations. The similar prevalence of bedbugs in the placebo group before and after treating the bednets strongly suggests that the populations of bedbugs are stable in these hamlets. Presumably the sheltered environment within a house, few predators, and the close proximity of a readily available food source contribute to this stability.

Visual searches of beds for bedbugs proved a simple and reasonably accurate method for detecting infestations. However, this was a dirty, physically demanding and time-consuming operation. We suggest a simpler method, suitable for large surveys, would be to restrict the inspection to corners of bednets and mattresses.

Drying permethrin-impregnated bednets on mattresses immediately after dipping probably contributed to the eradication of bedbugs and chicken ticks from previously infested beds. The resulting partial treatment of the mattress, as well as the bednet, with permethrin ensured little chance of a bedbug or tick avoiding the insecticide in its search for a bloodmeal. Both bedbugs and chicken ticks were considered to be major nuisances and their eradication was appreciated greatly by the inhabitants of the hamlets. However, a cautionary note is necessary since, in the past, DDT spraying programmes aimed at eradicating malaria have failed due to the development of insecticide resistance by bedbugs (Rafatjah, 1971). In some cases, increased bedbug densities after spraying led to 80% of households refusing to have their homes sprayed. The monitoring of insecticide resistance in bedbugs in situations where insecticide-treated bednets are used will be of paramount importance.

Whilst it has been suggested that pediculosis is primarily an urban problem (Mellanby, 1941; Donaldson, 1976; Ogurinade & Oyejide, 1984), our study in a rural area demonstrated a prevalence rate no less than in many urban areas in Africa (Grainger, 1980, Ogurinade & Oyejide, 1984; Chunge, 1986). *P.capitis* infections were clustered within compounds, implying that some children are more at risk than others, presumably from contact with their neighbours.

The prevalence of headlice was higher on girls than boys (Table 2). This may be because of behavioural difference between the sexes, with girls having greater head to head contact, and thus a higher risk of transmission, than boys. It may also be because girls more often groom the heads of other children to remove headlice, risking infestation of themselves in the process. The higher prevalence of headlice in European girls than boys is thought to be because of the usually longer hair of the girls (Buxton, cited by Busvine, 1980). Our study of African children demonstrated that both sex and hair length independently affect headlice prevalence. Headlice were more common in children with long hair than short (Table 2). Long hair may increase the likelihood of an infection with headlice for at least three reasons. Firstly, since the long hair of girls is often braided for neatness and fashion, it may remain plaited for several weeks, which is unfortunate since combing can be an efficient way of controlling headlice (Maunder, 1983). Braided hair has been recognized as a risk factor in acquiring headlice in other African studies (Kwaku-Kpikpi, 1982; Ogunrinade & Oyejide, 1984; Arene & Ukaulor, 1985). Secondly, children regularly have their scalps searched for headlice, usually by older children. It is easier to see and remove a louse from a child with short hair than with long hair. Lastly, the survival of a headlouse may be greater when protected from the severe tropical sun under an abundance of hair.

Significantly fewer flying and crawling insects, excluding earwigs, were found in homes where permethrin-treated bednets were used. Whilst this is likely to be a beneficial side-effect of the use of permethrin-treated bednets, it should be noted that no pre-intervention counts were made. The greater number of earwigs found in homes with permethrin-treated bednets compared with placebo-treated bednets may be a reflection of the habits of this insect. Earwigs presumably benefit from insecticide-treated bednets by scavenging the insects which make contact with the nets and lie dead or dying on the floor of the houses.

We have strong evidence that permethrin-treated bednets eradicated or severely reduced most nuisance arthropods found in the home. This was probably due to the lethal effect of the insecticide, assisted by a deterrent response. The real and perceived success of permethrin-treated bednets against domiciliary arthropods should encourage their acceptance by a community. This is a major benefit to malaria control programmes in which permethrin, and perhaps other pyrethroids, are used to treat bednets.

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