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Impact on malaria morbidity of a programme supplying insecticide treated nets in children aged under 2 years in Tanzania: community cross sectional study

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A table showing the impact of net use on anaemia reported by other trials is available on the BMJ's website. This article is part of the BMJ's trial of open peer review, and documentation relating to this also appears on the website

Abstract

Objective To assess the impact of a social marketing programme for distributing nets treated with insecticide on malarial parasitaemia and anaemia in very young children in an area of high malaria transmission.

Design Community cross sectional study. Annual, cross sectional data were collected at the beginning of the social marketing campaign (1997) and the subsequent two years. Net ownership and other risk and confounding factors were assessed with a questionnaire. Blood samples were taken from the children to assess prevalence of parasitaemia and haemoglobin levels.

Setting 18 villages in the Kilombero and Ulanga districts of southwestern Tanzania.

Participants A random sample of children aged under 2 years.

Main outcome measures The presence of any parasitaemia in the peripheral blood sample and the presence of anaemia (classified as a haemoglobin level of <80 g/l).

Results Ownership of nets increased rapidly (treated or not treated nets: from 58% to 83%; treated nets: from 10% to 61%). The mean haemoglobin level rose from 80 g/l to 89 g/l in the study children in the successive surveys. Overall, the prevalence of anaemia in the study population decreased from 49% to 26% in the two years studied. Treated nets had a protective efficacy of 62% (95% confidence interval 38% to 77%) on the prevalence of parasitaemia and of 63% (27% to 82%) on anaemia.

Conclusions These results show that nets treated with insecticide have a substantial impact on morbidity when distributed in a public health setting.

Introduction

Several studies have shown that malarial parasitaemia is positively correlated with anaemia and that parasitaemia is the primary cause of anaemia in very young children in Africa.[1] As a result, because malarial infection is the norm in high transmission areas, anaemia is common in young children. Assessment of the impact of chemoprophylaxis in Tanzanian infants showed that over 60% of the anaemia could be due to malaria.[2] The emergence and spread of parasite resistance to commonly used antimalarial agents has exacerbated the problem of anaemia in sub-Saharan Africa.[3]

Hopes for controlling malaria and malarial anaemia have recently been revitalised by the demonstration that nets treated with insecticide can reduce morbidity and mortality. A summary of randomised controlled trials showed an average protective effect of about 50% on mild malaria episodes in areas where the rate of transmission of malaria was stable.[4] Moreover, protective effects were shown on the prevalence of parasitaemia with a high level ($>5000/\mu l$) of trophozoites (31%) and on overall mortality (19%). A modest improvement in packed cell volume (a rise of 0.02 (2%)) and weight gain was also observed in children sleeping under treated nets.[4] Large scale implementation of programmes to supply treated nets is under way in several African countries.[5]

It is not known whether the impact of treated nets in the context of well controlled randomised controlled trials can be replicated under programme conditions.[6] We report the first assessment of the impact of treated bed nets when supplied in the context of a large scale social marketing programme (an approach using marketing techniques to promote and distribute socially beneficial interventions rather than commercial products) on morbidity indicators in children aged under 2 years in an area of Tanzania with a high prevalence of malaria.

Methods

Study area and population

Social marketing of treated bed nets started in the Kilombero net project (KINET) in 1997,[7] covering the

Kilombero and Ulanga districts (population 350 000) in southwestern Tanzania. Nets and insecticide (branded Zuia Mbu) are now being promoted, distributed, and sold through public and private outlets and a system of community door to door distributors. When the project began, the retail price of a treated net was $5 (£3.60). Although this amount was not a negligible part of the average annual income in this community, many of the residents bought a net.[7] The impact of the programme on morbidity and mortality indicators is being monitored in 18 villages under demographic surveillance. Population characteristics of this area of high perennial malaria transmission have been described elsewhere.[8] Moderate anaemia (packed cell volume <0.25 (<25%)) and severe anaemia occur in 61% and 14% respectively of children aged under 5 years who are admitted to the local St Francis District Hospital.[9] Resistance to chloroquine is common: 65% of malaria infections do not clear within one week of chloroquine treatment.[10]

Design

Three annual, cross sectional surveys were conducted in a sample of children aged under 2 years living in the villages in the demographic surveillance area.[7] The first survey was done at the time of launching the social marketing campaign in June 1997, and two other surveys were carried out at the same period (June to August) in the subsequent two years. A simple random sample was selected from the demographic surveillance database for the first survey, and a two stage, random sampling (of six villages then sampling children from these) was done for the subsequent surveys. A different sample was selected for each survey.

We obtained ethical approval for the study from the Ifakara Health Research and Development Centre and the Tanzania Commission of Science and Technology.

Procedures

The selected children were visited at home, and oral consent obtained from the parent or guardian. A questionnaire was used to assess use of treated nets and other potential risk factors. A physical examination was performed, and temperature, weight, and height were also measured. A finger prick blood sample was taken to determine haemoglobin level and assess whether parasitaemia was present. Haemoglobin levels were measured with a portable kit, HemoCue (HemoCue, Ängelholm, Sweden). Slides were stained in Giemsa and were read (without the microscopists knowing the child's net status) using standard procedures as described elsewhere.[9] An inspection of the children's sleeping places to assess their use of nets was done only in 1999 because this was strongly perceived as an intrusion of their privacy.

Anaemia was classified as a haemoglobin level of (<80 g/l) as this is the level that has been associated with increased mortality[11] and is consistent with earlier studies in Tanzania.[2] Parasitaemia and splenomegaly were classified as either present or absent. Use of treated nets was categorised on the basis of the respondents' answers on ownership and if the nets were "ever treated" or "not treated." No simple field methods exist for assessing insecticide content in nets.

Data analysis

Analysis was done for the three cross sectional surveys combined. We estimated impact of the nets on haemoglobin level, anaemia, parasitaemia, and splenomegaly using multiple linear and logistic regression models, taking into account the sampling methods for years 2 and 3, and using robust regression approaches in STATA software.[12] We included the effect of different time points of observation (surveys) as one of the explanatory variables.

We also included in the multivariate models the use of a net, condition of the net, age, sex, ethnicity, religion, nutritional status, and access to a dispensary, shops, and covered wells. Treatment history and "health seeking" attitudes were also included, as were factors related to family size and income.

Results

We identified 985 eligible children; the mothers of 16 of these children refused consent, and 142 mothers could not be traced at their homes. Therefore, mothers (or guardians) of 827 children were interviewed during the three cross sectional surveys. Sixty eight children were over 24 months old at the time of sampling, and the net status was not known for 11 children; therefore only 748 (91%) children were included in the analysis. Similar proportions of anaemia and of reported net ownership were found in the children analysed and those not analysed (data not shown).

We observed an increase in the mean haemoglobin level from 80 g/l to 89 g/l and a decline in the proportion of children with anaemia (49% to 26%), parasitaemia (63% to 38%), and splenomegaly (86% to 49%) during the successive surveys (table 1). The proportion of children with a net (treated or untreated) increased from 58% (140/240) to 83% (199/239), and those with treated nets increased substantially during the three years (from 10% to 61%), indicating a rapid uptake of the socially marketed treated nets, especially during the first year (table 1).

Ownership and use of nets

Predictors of net ownership included family income: families with a high income (highest quarter) were almost three times more likely to have a bed net than those with a low income (lowest quarter) (table 2). This

Table 1 Characteristics of children surveyed in three cross sectional surveys, 1997-9. Values are numbers (percentages) of children unless stated otherwise

Year	1997	1998	1999	Overall
Eligible	325	330	330	985
Interviewed	269 (83)	291 (88)	267 (81)	827 (84)
Analysed	240 (74)	269 (82)	239 (72)	748 (76)
Children analysed				
Mean (range) age (months)	14.2 (3.3-26.4)	13.5 (3.0-24.7)	15.4 (2.4-25.5)	14.4 (2.4-26.4)
Male	122 (51)	137 (51)	113 (47)	372 (50)
Mean (SE) haemoglobin (g/l)	80 (1.2)	89 (1.0)	89 (1.0)	86 (0.7)
Children with anaemia (haemoglobin <80 g/l)	118 (49)	83 (31)	62 (26)	263 (35)
Children with parasitaemia	151 (63)	126 (47)	90 (38)	367 (49)
Children with splenomegaly	207 (86)	144 (54)	117 (49)	468 (63)
Reported net ownership:				
No net	100 (42)	49 (18)	40 (17)	189 (25)
Untreated net	116 (48)	64 (24)	53 (22)	233 (31)
Treated net	24 (10)	156 (58)	146 (61)	326 (44)

Table 2 Predictors of ownership of bed nets (logistic regression analysis: final model also included ethnic origin of child)

Variable	No (%) of children with nets	Adjusted odd ratio (95% CI)	χ^2 test (P value)*
Income categories (quarters of total family income):			
First (lowest)	124/185 (67)	Reference group	
Second	130/184 (71)	1.25 (0.59 to 2.66)	
Third	142/195 (73)	1.13 (0.74 to 1.72)	
Fourth (highest)	163/184 (89)	2.74 (1.58 to 4.75)	8.89 (0.031)
No access to covered wells†	191/245 (78)	0.61 (0.41 to 0.90)	3.90 (0.048)
Advised neighbours to get care for their sick children:			
At formal health facility	387/464 (83)	2.27 (1.38 to 3.72)	3.90 (0.048)
From traditional healer	1/3 (33)	0.12 (0.01 to 1.07)	2.97 (0.085)
Child immunised	376/447 (84)	1.92 (0.86 to 4.29)	3.38 (0.066)
Mother educated	395/500 (79)	1.59 (0.85 to 3.00)	3.15 (0.076)

CI=confidence interval. *Likelihood ratio test. †Piped clean water.

Table 3 Impact of nets on prevalence of any parasitaemia (logistic regression analysis: final model also included stunting, no access to covered wells, and sex)

Variable	No (%) of children with parasitaemia	Geometric mean for parasite density	Adjusted odd ratio (95% CI)	χ^2 test (P value)*
No net	132/189 (70)	4404	Reference group	
Untreated net	115/233 (49)	2890	0.49 (0.24 to 1.00)	
Treated net	120/326 (37)	2745	0.38 (0.23 to 0.62)	8.75 (0.013)
Use of net in past month	107/315 (34)	3291	0.53 (0.35 to 0.79)	6.69 (0.010)
Ethnic group:				
Ndamba	49/136 (36)	3901	Reference group	
Pogoro	76/114 (67)	3423	3.78 (1.62 to 8.87)	
Hehe	42/97 (43)	4315	1.53 (0.74 to 3.16)	
Other	209/409 (51)	3070	2.48 (1.27 to 4.84)	14.63 (0.002)
Age (months):				
0-6	17/61 (28)	2040	Reference group	
7-12	106/245 (43)	2710	3.00 (0.95 to 9.44)	
13-18	114/204 (56)	4111	3.64 (1.31 to 10.14)	
>18	140/248 (56)	3622	4.85 (1.57 to 14.96)	13.4 (0.004)
Religion:				
Other than Muslim or Catholic	52/127 (41)	4434	Reference group	
Muslim	157/267 (59)	2967	2.40 (1.32 to 4.35)	
Catholic	159/351 (45)	3404	1.54 (1.00 to 2.37)	8.85 (0.012)

CI=confidence interval. *Likelihood ratio test.

was expected as the treated nets were being sold. By the end of the second year of the marketing campaign (1999), only 17% of the children were without a net. Children with no access to covered wells (piped clean water)—that is, not at the centre of the villages—were less likely to have nets (table 2). Mothers who mentioned that they would advise their neighbours to send their sick children to a formal health facility were more likely to have nets for their own children (odds ratio 2.27; likelihood ratio test $\chi^2=3.90$, P value=0.048) than mothers who advised care by a traditional healer. This might reflect an association between health seeking patterns or perceptions about the value of the formal health system and the decision to have a net or not.

Table 4 Impact of treated bed nets on prevalence of anaemia (haemoglobin <80 g/l) (logistic regression analysis: final model also included distance to a shop, use of net in previous month, immunisation status, and age and sex of child)

Variable	No (%) of children with anaemia	Adjusted odd ratio (95% CI)	χ^2 test (P value)*
No net	103/189 (54)	Reference group	
Untreated nets	90/233 (39)	0.63 (0.27 to 1.46)	
Treated nets	70/326 (21)	0.37 (0.19 to 0.73)	9.58 (0.008)
Stunted height (z score ≤−3)	109/213 (51)	2.53 (1.66 to 3.84)	12.95 (<0.001)
No access to covered wells†	87/245 (36)	1.95 (1.24 to 3.07)	7.64 (0.006)
Religion:			
Other than Muslim or Catholic	40/127 (31)	Reference group	
Muslim	112/267 (42)	1.80 (0.97 to 3.36)	
Catholic	113/351 (32)	0.96 (0.58 to 1.58)	7.31 (0.026)
Advised neighbours to get care for their sick children at formal health facility	125/465 (27)	0.45 (0.19 to 1.11)	4.12 (0.042)
Mother educated	179/501 (36)	1.53 (0.87 to 2.68)	2.93 (0.087)

CI=confidence interval. *Likelihood ratio test. †Piped clean water.

Observation of sleeping places for 171 children in 1999 showed that 117 of the 126 (93%) mothers who claimed to be using nets had a net hanging at the sleeping place. For all nine children who had a missing net at the sleeping place, we were shown a net claimed to be used. Among those who claimed not to be using nets, 17% (8/45) had a net hanging at the sleeping place. Eight of the 45 (17%) mothers who claimed not to be using nets had a net hanging at the sleeping place. These observations showed that reported ownership and reported use provided a reasonable basis for defining net status.

Health impact of treated nets

We observed a protective efficacy—defined as (1 − odds ratio)×100—on the prevalence of parasitaemia of 62% (95% confidence interval 38% to 77%) and 51% (0% to 76%) for treated and untreated nets respectively, when compared with children without nets (table 3). The prevalence of parasitaemia was also related to ethnic group, religion, use of the net in the previous month, and age of the child, with the prevalence in those aged over 1 year being four times higher than that in those aged under 7 months (table 3). This is consistent with earlier studies in Tanzania that showed that prevalence of parasitaemia increased with age.[13 14]

The mean haemoglobin level was 77 g/l (95% confidence interval 74 g/l to 79 g/l) in children without nets, 86 g/l (83 g/l to 88 g/l) in those with untreated nets, and 92 g/l (90 g/l to 93 g/l) in those with treated nets. Multiple regression analysis showed that haemoglobin level increased by 13 g/l (8 g/l to 17 g/l) in those with treated nets and by 11 g/l (5 g/l to 17 g/l) in those with untreated nets, compared with those with no nets. On the basis of our classification of anaemia, a protective efficacy of 37% (−46% to 73%) for untreated nets and 63% (27% to 82%) for treated nets was observed. Children whose height was stunted or who had no access to covered wells were more likely to be anaemic (table 4). If the cut-off level for anaemia was set at 110 g/l, the protective efficacy of untreated nets was 78% (29% to 93%) and of treated nets was 82% (42% to 94%). Parasitaemia was associated with anaemia: children with severe parasitaemia had lower mean haemoglobin levels than those with no or mild parasitaemia (χ^2 for trend, $P<0.001$). Lastly, nets also had a high impact on prevalence of splenomegaly, with a protective efficacy of 71% (39% to 87%) for children with untreated nets and 76% (52% to 88%) for those with treated nets.

In children without nets the prevalence of anaemia remained relatively stable (49% to 58%) over the study period; this was also the case for the prevalence of parasitaemia (68% to 71%). This suggests that the transmission rate of malaria did not change substantially during the study.

What is already known on this topic

Randomised controlled trials of materials treated with insecticide have consistently shown short term impact on malaria morbidity and mortality

Whether these benefits can still be observed when such materials are distributed in public health programmes is not known

What this study adds

Bed nets treated with insecticide and distributed as part of a large scale social marketing programme can rapidly and substantially reduce the prevalence of malarial parasitaemia and anaemia in very young children

Discussion

These results have shown that the social marketing approach of distributing bed nets treated with insecticide was highly successful and resulted quickly in more than 80% of children aged under 2 years having access to a net. Our results suggest a good overall impact of social marketing of treated nets on health outcomes in the community, with an improvement of mean haemoglobin levels (from 80 g/l to 89 g/l) and a decline in the total proportion of children with anaemia (from 49% to 26%), parasitaemia, or splenomegaly. The treated nets had an apparent individual protective efficacy of over 60% on the prevalence of anaemia, parasitaemia, and splenomegaly. In this study untreated nets were also found to be protective. Overall, most of the changes occurred in the first year of the study.

These efficacy estimates are higher than those found in most controlled trials (see table on the *BMJ*'s website).[w1-w11] May this finding be the result, therefore, of residual confounding despite efforts to control for it? This question is especially pertinent because our comparison group comprised children who did not own nets in the same community. The tools used to measure confounding factors such as socioeconomic status and health seeking behaviour may not be sensitive enough to allow for proper control of confounding. Factors related to the dynamics of the malaria infection and the associated disease presentation, however, may also explain this finding. Variations in transmission, for example, strongly affect the estimates of morbidity and mortality in very young children.[15] Therefore at a given transmission intensity, the age of the study participants may be crucial in determining the level of protection. Our finding of high impact in children under 2 years is in line with other studies that included very young children (see website table).

Lower impact estimates than ours were observed in a randomised study near Ifakara in a similar age group.[w11] This may be because our study covered a larger geographical area and included study children with a lower mean haemoglobin level (mean level in those without nets 77 g/l in our study, 87 g/l in the Ifakara study, t test = 3.9, P = 0.0001). Children with more severe anaemia are probably more likely to benefit from intervention than children with milder anaemia.

Nets treated with insecticide distributed through a social marketing programme rapidly and substantially reduced the prevalence of parasitaemia and anaemia in children aged under 2 years. This strategy has high potential in the control of malaria in sub-Saharan Africa.

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Contributors: SA contributed to the design and planning of the work and was responsible for the field implementation, the analysis and interpretation of the data, and the writing of the paper. JAS has substantially contributed to the design, implementation, analysis and interpretation of the data, and in the writing of the paper. RN, OM, and TM participated in different ways in the design of the study, participated in the implementation of the field work and in the management and interpretation of the data, and contributed to the editing of the article. TS contributed to the design of the study, to its data management and analysis, and to the writing and finalisation of the paper. MT was involved in the planning and supervision of the work and contributed to the analysis and the writing of the paper. CL had overall responsibility for the work and contributed to all key aspects, including the interpretation of the findings and the writing of the paper. SA, JAS, CL will act as guarantors for the paper.

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Competing interests: During the past five years CL has received financial support from several manufacturers of insecticide and mosquito nets to attend scientific meetings.

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