Tropical Medicine and International Health

VOLUME 8 NO 8 PP 693–703 AUGUST 2003

Monitoring mosquito net coverage for malaria control in Africa: possession *vs.* use by children under 5 years

Eline L. Korenromp[1], John Miller[1], Richard E. Cibulskis[1], M. Kabir Cham[1], David Alnwick[1] and Christopher Dye[2]

1 *World Health Organization, Roll Back Malaria Monitoring and Evaluation, Geneva, Switzerland*
2 *World Health Organization, StopTB, Tuberculosis Monitoring and Evaluation, Geneva, Switzerland*

Summary

OBJECTIVES To investigate the strengths and weaknesses of the indicators 'proportion of households possessing mosquito net(s)' and 'proportion of children under 5 years of age who slept under a net the preceding night' for monitoring malaria control.

METHODS Review of data from household surveys including demographic and health surveys in sub-Saharan African countries.

RESULTS Net possession ranged among 14 surveyed regions from 0.1% to 28.5% for insecticide-treated nets (ITNs) and among 69 regions from 3.6% to 79.7% for any net. Reported use during the preceding night by children under 5 years of age was between 0% and 16% for ITNs and between 0.7% and 74.5% for any net. On average, in households owning ITN(s), 55% of children slept under it ($R^2 = 0.97$, $P < 0.001$). For any net, use was −4.2% + 0.875 × possession ($R^2 = 0.89$, $P < 0.001$); the use of nets, however, also varied somewhat among the surveyed countries ($P = 0.003$). In-depth surveys suggested that use was lower than possession because: (i) nets were scarce (mean 1.8 per possessing household); (ii) nets were not always used for children and (iii) use was lower during hot, dry months than during cool rainy months, and many surveys had been conducted in the dry season.

CONCLUSIONS Not all mosquito nets owned by African households are being used for young children. Household education on the consistent use of nets for this vulnerable group is called for in malaria control programmes. Regular, district-level rapid assessments of household possession of nets should complement ongoing in-depth surveys. Data on 'use during the preceding night' must be interpreted taking the survey season into account.

keywords malaria – prevention and control, measurement, demographic and health surveys, monitoring, insecticide-treated mosquito nets

Introduction

Use of insecticide-treated mosquito nets (ITNs) for protection against mosquito bites during sleep is a highly effective and cost-effective intervention against malaria. In endemic areas, children under 5 years of age are especially vulnerable to malaria and are likely to benefit most from the use of nets. Community-based randomized trials in Africa have documented average reductions of 20% in all-cause under-5 years mortality within 2 years of increasing ITN use from 0 to 50–70% (D'Alessandro *et al.* 1995a; Binka *et al.* 1996; Nevill *et al.* 1996; Habluetzel *et al.* 1997; Lengeler 2000). Based on this evidence, programmes of ITN promotion through social marketing, tax exemption and health education started in many countries during the 1990s. The Roll Back Malaria partnership has set a coverage target for Africa of 60% of children under 5 years of age sleeping under ITNs by 2005 (Roll Back Malaria 2000a).

An imperative for Roll Back Malaria is to monitor progress towards this target, so that shortfalls in implementation can be identified and acted upon. Two indicators that are of potential value are (i) the proportion of households that have one or more nets and (ii) the proportion of children under 5 years of age who use (i.e. sleep under) a net (Roll Back Malaria 2000b). Household possession data indicate the extent to which distribution channels are enabling high coverage and may be particularly valuable at the early stages of programme development and implementation. Use of mosquito nets, however, is, of course, what affords protection and is therefore a more useful predictor of epidemiological impact. In practice, both measures will be useful for programme management. If use rates are low, it is important to know whether this is due to affordability and a lack of availability, or the failure to use available nets which would suggest a need for health education. However, the cost implications of collecting data for the two indicators are different. Possession requires only a single question to any household member, whereas use requires additional questions on the behaviour of specific, enumerated household members and therefore involves greater investment. Use is also subject to seasonal variation, so that data collected at different times of the year in rapid surveys may not be comparable between populations.

Monitoring of both indicators has gained momentum since 1998 with the inclusion of questions on malaria prevention in the nationally representative demographic and health surveys (DHS) (ORC Macro/Measure DHS) that are conducted in an increasing number of malaria-endemic countries. Since 1999, DHS surveys in nine countries have provided estimates of net possession and use at household level. In addition, in 2000/2001, UNICEF conducted some 25 multiple indicator cluster surveys (MICS) on child health in malaria-endemic countries, including net use (not possession) (UNICEF 2001).

This paper examines the relationship between household possession and use of ITNs and untreated nets in DHS and other population-based surveys in African countries. We also explore other determinants of the effective use of nets by children, such as seasonality and correctness of use. Based on available data, we discuss the options for optimizing monitoring at (sub-)country level.

Methods

Household surveys

Household surveys on net use and possession in African malaria-endemic countries were identified on Internet sites of international survey organizations and by PubMed search using combinations of the keywords: bedding and linens, mosquito control, malaria/prevention & control, insecticides/therapeutic use, questionnaires, and textwords: cover*, possess*, sleep*, use*/using/use, bednet*. Possession was defined as the fraction of households that (said they) owned at least one net. The use was defined as 'reported to have slept under the net during the night preceding the survey', but if the report or publication had not been specified this, 'always' use (as opposed to 'ever' or 'sometimes') was considered instead. For use, only outcomes dealing with children under 5 years of age were considered. Besides insecticide-treated nets, untreated nets were also considered, because these have a significant epidemiological impact in their own right and may be as cost-effective as ITNs (D'Alessandro *et al.* 1995b; Clarke *et al.* 2001; Guyatt & Snow 2002). In addition, the coverage with untreated nets indicates the potential for future coverage with ITNs, and issues of measurement are largely the same for both types of nets. As the impregnation status of nets was not always reported, the categories used were ITNs and any nets.

A main source of data were the DHS (ORC Macro/Measure DHS), conducted on average at 5-year intervals in many malaria-endemic countries. Typically, a DHS consisted of 4000–8000 interviews with women aged 15–49 years living in households that are sampled in a multiple-stage cluster design. The standardized questionnaire addresses, amongst others, household living conditions and assets and child health, through birth histories. By appropriate weighing between sampling units, nationally representative estimates can be obtained. Since 1998, some DHS have used specific questions on malaria prevention and treatment, including possession of mosquito nets and their use for children and pregnant women. Since 2001, most of these questions have been grouped in a malaria module, to be used in all surveys conducted in malaria-endemic countries. Another large source of data was the baseline surveys of net-promotion projects conducted in six African countries in 2000 under the Netmark initiative; each survey interviewed women in 1000 households spread over four or five districts (Netmark 2001). These data were pooled over the districts with urban–rural stratification. For countries where there had been no DHS or netmark survey, incidental surveys conducted in multiple regions or single districts were eligible.

As bednet possession and use can vary greatly among geographical areas within countries and the usefulness of net-coverage data as feedback for programme planning is at district level, our unit of analysis was the subnational level, and most often the provincial level. For DHS, we followed subnational grouping provided in published reports, which sometimes differed from provinces. Where data were not available by subnational region but included a distinction between rural and urban parts of the area, outcomes for these two groups were included separately. For the remaining surveys, national values were used.

Analysis of use *vs.* possession

The dependence of net use by children on net possession was analysed by least-square multivariate linear regression in SPSS version 10.0.7 (SPSS Inc.), in which the country of survey was allowed as a categorical variable. Each surveyed region was weighted equally, irrespective of its sample size, assuming the variation in outcomes to derive mainly from population- and study-specific characteristics and not from sampling imprecision in the generally large surveys.

Subsidiary analyses

In order to explore the reasons for the difference between possession and use, we also considered smaller-scale surveys conducted at a sub-district level. Questions were asked on – numbers of nets per household, use by household members other than children and seasonality in use; alternatively, the presence and condition of the nets were inspected visually. These surveys included evaluations during social marketing projects and the baselines and comparison arms of mosquito net intervention trials.

The month when the DHS and netmark fieldwork surveys were performed was compared with the months which the long-term variation in climate renders suitable for malaria transmission, as predicted by a model of malaria seasonality (Tanser *et al.* 2003). The model predicts the start month and duration of the malaria season, based on mean rainfall and temperature conditions available at grids of 5×5 km^2 (Hutchinson *et al.* 1995). Transmission seasons may start in different months and last for a longer or shorter duration in different parts of given countries; this comparison was therefore made at the subnational level that corresponded to the levels of the bednet surveys (usually the province). To find the most representative malaria transmission season for the district, the surface area characterized by each particular seasonal pattern (start month and duration) was calculated. The pattern applying to the greatest proportion of the area was used to represent that district.

Results

We identified 13 surveys with paired data on net use by children and net possession by households, conducted between 1991 and 2001. Six were DHS, one an incidental national survey (D'Alessandro *et al.* 1994), five Netmark programme baseline surveys (Netmark 2001) and two incidental surveys in one district (Hamel *et al.* 2001) and four districts (Ochola & Snow 2002). In 69 surveyed regions (from 12 countries), possession varied between 0.1% and 28.5% for ITN; for any net, the range over 14 surveyed regions (from six countries) was 3.6–79.7%. Corresponding use during the preceding night by children under 5 years of age was 0% to 16% and 0.7% to 74.5%, respectively.

Children's use increased with possession (Figure 1). In a linear fit, for ITNs, the use was 0.55 as high as possession (i.e. 0.55 was the slope of the least-square fitted linear model equation, see Appendix). For any nets, use was −4.2%(intercept) + 0.875(slope) × possession, indicating that, on average, only at possession levels of over 4.2% were nets used for children. These correlations were statistically significant ($R^2 = 0.97$, $P < 0.001$ for ITN; $R^2 = 0.89$, $P < 0.001$ for any net). Possession could predict child use within a 95% CI of 4–5% points for ITN and 21–24% points for any net (error envelopes in Figure 1). When analyses were performed at country level, i.e. ignoring subnational variation, results were qualitatively the same (not shown).

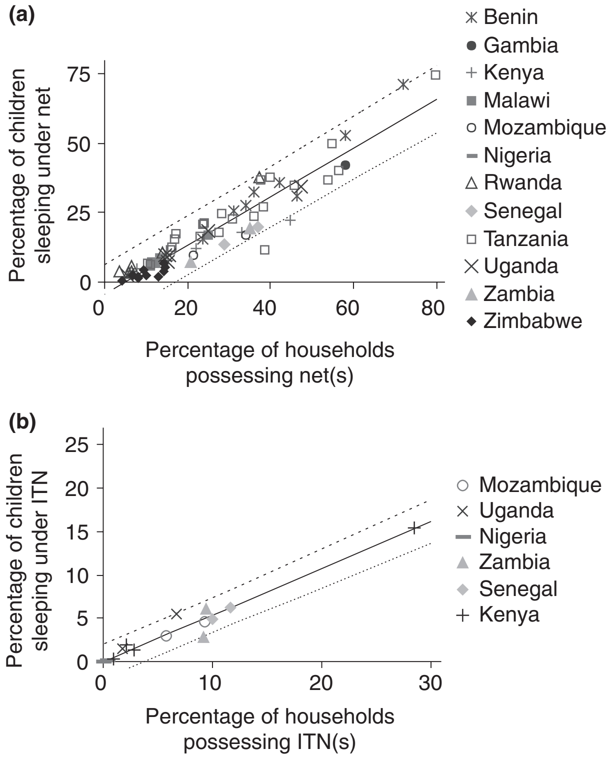

Figure 1 Correlation between reported household possession and use for children under 5 years of mosquito nets in Africa. (a) any nets, (b) insecticide-treated nets (ITNs). Symbols indicate the surveys or surveyed subcountry regions; solid lines a prediction of reported use from possession (pooled across surveyed regions); dashed lines the 95% confidence interval on the prediction. Reported use refers to the night preceding the survey or 'always'. The prediction line for 'any net' ignores a significantly greater use given possession for Rwanda (see Appendix). Sources: Benin 2001, Malawi 2000, Rwanda 2000, Tanzania 1999, Uganda 2000, Zimbabwe 1999 (ORC Macro/Measure DHS); Mozambique 2001, Nigeria 2001, Senegal 2001, Zambia 2001, Uganda 2001 (Netmark 2001); The Gambia 1991 (D'Alessandro *et al.* 1994), Kenya (Hamel *et al.* 2001; Ochola & Snow 2002).

For any net, however, use also depended significantly on the country ($P = 0.003$), with use given a certain level of possession being relatively high for Rwanda ($P = 0.011$, Appendix). In this regression model, the influence of possession nevertheless remained similar, with child use of any net increasing by 0.86% for every extra household possessing bednets ($P < 0.001$). No interactions between possession and country of survey were identified, i.e. the influence of possession on children use did not vary among the countries.

To explain why use was lower than possession, the numbers of nets were compared with numbers of residents per household from surveys that recorded this (Table 1). The number of nets present in a household (mean ± SD) (1.8 ± 0.35) approximated the number of children under 5 years of age (1.9 ± 0.77). The total number of household members was on average 5.5 ± 0.94. Among surveys where this could be calculated, the average ratio of children to nets was 1.2 ± 0.53:1, and the ratio of household members to nets was 3.4 ± 0.51:1. This suggests that the average number of nets in a household would typically not suffice to cover all residents. However, the inference does not allow for sharing of beds and nets between adults, children or children and adults (e.g. infants and their mothers), on which we lack quantitative data.

A more direct comparison of reported age-specific use revealed that, within households, coverage of young children with any net was often as high as or higher than for adults, although the inverse pattern was found in Zimbabwe, Kenya, Rwanda and Burkina Faso (Figure 2; difference between adults and children $P = 0.80$ in two-tailed paired *t*-test). It thus appears that young children are not at a disadvantage in the allocation of scarce nets within households, but neither are they favoured. For ITN, children were slightly more often protected than adults ($P = 0.016$ in two-tailed paired *t*-test). This result contrasts with the larger gap between possession and child use for ITNs when compared with any nets; being based on only five Netmark surveys conducted in 2000, however, the generalizability of these comparative ITN use levels to other areas and years is not clear. The comparative use by children and adults did not detectably depend on any characteristic of the surveys, such as region or calendar year.

In a survey in Kampala, Uganda, net use for young children during the preceding night increased with the number of nets present in the household, being 35% for (any) children under 5 years of age and 78% for (any) adults in households with one net, when compared with 69% for children and 47% for adults in households with two or more nets; the odds ratio of any child sleeping under a net was 12.6 (95% CI 5.4–29.5) for households with two or more nets compared with households with one net (Kampala City Council 2002).

Another reason for lower use than possession was that nets were not used on all days in all seasons. In surveys in Ghana, Gambia and Kenya, net use was between 1.2 and 5.0 times higher in the rainy, cooler months than in the dry and hotter months (Figure 3). The lower use in dry and hot months related to less mosquito nuisance and sometimes to the perceived greater discomfort of sleeping under a net in this season (Binka *et al.* 1996). In comparison, most of the surveys that compared possession with use (Figure 1) had been conducted within a short period of time, precluding an assessment of seasonality in use. DHS fieldwork takes place throughout the year but usually avoids the wet season; Netmark surveys were conducted in September and October. Comparing the dates of fieldwork with the local season of malaria transmission (Tanser *et al.* 2003), the DHS in Uganda and Netmark surveys in Uganda, Senegal and Nigeria were for three quarters or more of the sampled clusters conducted during the malaria (rainy) season (Figure 4). In contrast, the Malawi and Zimbabwe DHS and the Netmark survey in Zambia were conducted entirely outside the malaria season.

Finally, even in the malaria season, not all existing nets are being used, as shown in a number of in-depth surveys that compared net use reporting with visual inspections of sleeping places (Table 2). Observations in a social marketing programme in Burundi showed that 29% of identified ITNs had not been hung up for use during the malaria-transmission season (Van Bortel *et al.* 1996). Moreover, visual inspections in houses revealed the frequent use of damaged or incorrectly hung nets.

Discussion

This review of indicator data on mosquito net coverage from published reports of surveys in Africa highlights several important issues for the monitoring and further implementation of this malaria prevention strategy. The proportion of children under 5 years of age who slept under a net during the night preceding a survey was considerably lower than the proportion of households that possess a net. This was especially true of ITNs. The larger gap between possession and use by children for ITN than for any nets may reflect either the relative scarcity of ITNs, or this may be an artefact of the little data that are yet available on ITN.

The gap is of concern for malaria control programmes: not only are young children the most vulnerable to malaria in most of sub-Saharan Africa (except epidemic areas), but nets are also relatively effective for this group. Their long sleeping hours will more often include the dusk hours of greatest mosquito abundance than do the sleeping hours of adults. The 'cost-efficiency' of using mosquito nets for young children deserves emphasis in community education activities that accompany net distribution. The discrepancy

Table 1 Numbers of nets and persons per household in African surveys

Reference	Setting	Population sampled and size	Number of nets per HH with ≥1 net(s)	Number of children <5 year per HH	Number of persons per HH
Marchant *et al.* (2002)	Rural Tanzania, 1998–1999	289 HH with pregnant women and ITN(s)	1.5	3.8 (DHS 1999)	Rural 5.3 (DHS 1999)
Kampala City Council (2002)	Kampala, Uganda, 2000	180 HH	2.3		
Nuwaha (2001)	Mbarara, Uganda, 1999	643 HH	1.4	1.3	5.2
Netmark (2001)	Five districts, Uganda, 2000	Urban 405 HH, rural 595 HH	Urban 1.8, rural 1.7	Urban 1.5, rural 1.6	Urban 4.5, rural 4.9
Netmark (2001)	Five districts, Mozambique, 2000	Urban 400 HH, rural 599 HH	Urban 1.5, rural 1.6	Urban 1.7, rural 1.7	Urban 5.7, rural 5.7
Holtz *et al.* (2002)	Blantyre, Malawi, 2000	138 HH with ITN(s) and children <5 years	1.7	1.3	5.0
Netmark (2001)	Five districts, Zambia, 2000	Urban 404 HH, rural 596 HH	Urban 1.5, rural 1.3	Urban 1.7, rural 1.7	Urban 6.0, rural 5.8
Chambon *et al.* (1997)	Three urban + three rural sites, Cameroon, 1994	Urban 701 HH, rural 488 HH	Urban 1.9, rural 1.7		Urban 6.5, rural 6.5
Netmark (2001)	Five districts, Nigeria, 2000	Urban 399 HH, rural 600 HH	Urban 1.4, rural 1.3	Urban 1.5, rural 1.7	Urban 4.8, rural 4.8
Van Bortel *et al.* (1996)	Nyanza Lac project, Burundi, 1994/1995	975 HH	1.7	2.3 (children any age)	4.4 (2.2 beds)
Okrah (2002)	Nouna + 10 villages, Burkina Faso, <2000	103 HH with nets	2.0		
Netmark (2001)	Five districts, Senegal, 2000	Urban 400 HH, rural 600 HH	Urban 1.8, rural 2.2	Urban 1.9, rural 2.0	Urban 7.0, rural 8.0
Agyepong & Manderson (1999)	Rural + urban Greater Accra, Ghana, 1992–1993	Rural 256 HH Urban 213 HH	Urban 1, rural 4		'Similar to number of nets'
Mean (± standard deviation)			1.8 ± 0.35	1.9 ± 0.77	5.5 ± 0.94

HH, household (unless indicated: including households without nets); ITN, insecticide-treated net; DHS, demographic and health survey. Unless indicated: average value. For cross-survey averages, the urban and rural parts of surveys were pooled; all surveys were weighted equally.

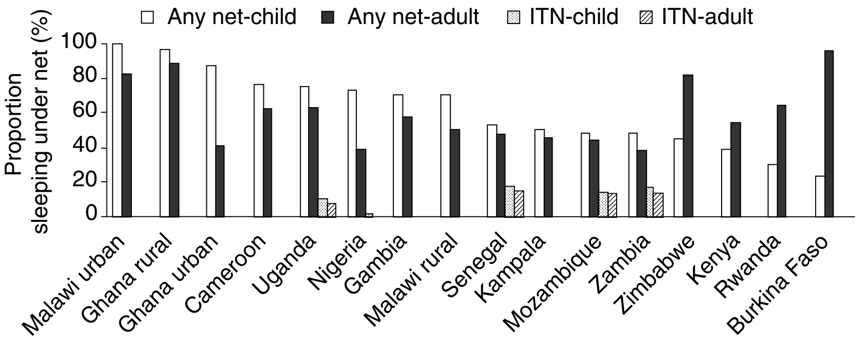

Figure 2 Comparative proportions (%) of adults and children under 5 years sleeping under a net, in households possessing at least one net. Burkina Faso: sum of 4% children <15 years alone and 19% young children with their mothers (Okrah 2002). Timing of use: preceding night for Malawi, Senegal, Nigeria, Zambia, Uganda, Rwanda and Mozambique (McAfee *et al.* 1997; Netmark 2001; Holtz *et al.* 2002; Kampala City Council 2002); preceding 7 days for Kenya (Kachur *et al.* 1999); undefined for Gambia, Ghana, Cameroon and Burkina Faso, Zimbabwe (Desfontaine *et al.* 1990; D'Alessandro *et al.* 1994; Stallworthy 1997; Agyepong & Manderson 1999; Okrah 2002).

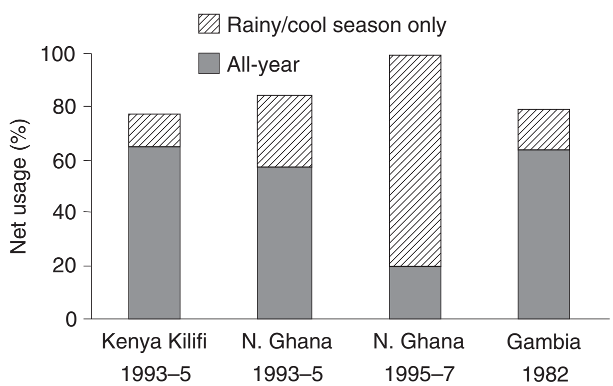

Figure 3 Seasonal variation in net use, by individuals reporting to use nets. Kenya: children, Ghana: mothers and children, The Gambia: undefined/household in general (Bradley *et al.* 1986; Binka *et al.* 1996; Nevill *et al.* 1996; Binka & Adongo 1997). In comparison, malaria transmission occurs in these surveyed districts: year-round in Kilifi/coast, Kenya; between June and December in Kassena-Nankana, Northern Ghana; and between July and December in Farafenni, North Bank, The Gambia (MARA 1995; Craig *et al.* 1999).

between possession and use by children was remarkably consistent across countries and subregions, suggesting that, at the time of these surveys, net use for the protection of children was not being adequately promoted in most African countries. However, the supra-district level of our analysis might have obscured subtle true geographical variation, e.g. the existence of districts or villages where child use was comparatively better because of successful local programmes. This explanation is supported by a comparatively large variation in child use levels of nets in net-owning households among the small-scale surveys compared in Figure 2.

Net possession could predict what reported child use would have been, within a certain margin. From recent DHS, MICS and Netmark surveys, in fact more data are available on use (e.g. for ITN from 30 African countries) than on possession (e.g. for ITN from eight African countries). However, such predictions are valuable for regions that are not covered by birth history surveys measuring child use but that do have surveys on household assets including net possession. The latter surveys include the Living Standard Measurement Surveys (World Bank 2003) and the Omnibus consumer surveys conducted commercially in an increasing number of African countries (http://www.mrgrad.net/whatis.htm). For rapid assessments, inference of child use from possession measured in a random selection of households might also be useful.

However, caution should be exercised in the predictions. For any net, use varied somewhat among the 12 surveyed countries, even though these surveys covered only a (published) subset of existing data. It is conceivable that other countries differ further from the surveyed countries, e.g. depending on their previous tradition of (untreated) net use. For example, in a survey in rural Burkina Faso with use levels of 96% for adults and 23% for children under 5 years in households with nets, the discrepancy between use and net possession by children, which had not been measured here, must have been at least 4.2-fold (Okrah 2002). Furthermore, the statistical uncertainty inherent in the prediction might obscure subtle improvements in use by children.

In surveys in The Gambia, Ghana and Kenya that reported on seasonal distribution, net use was considerably

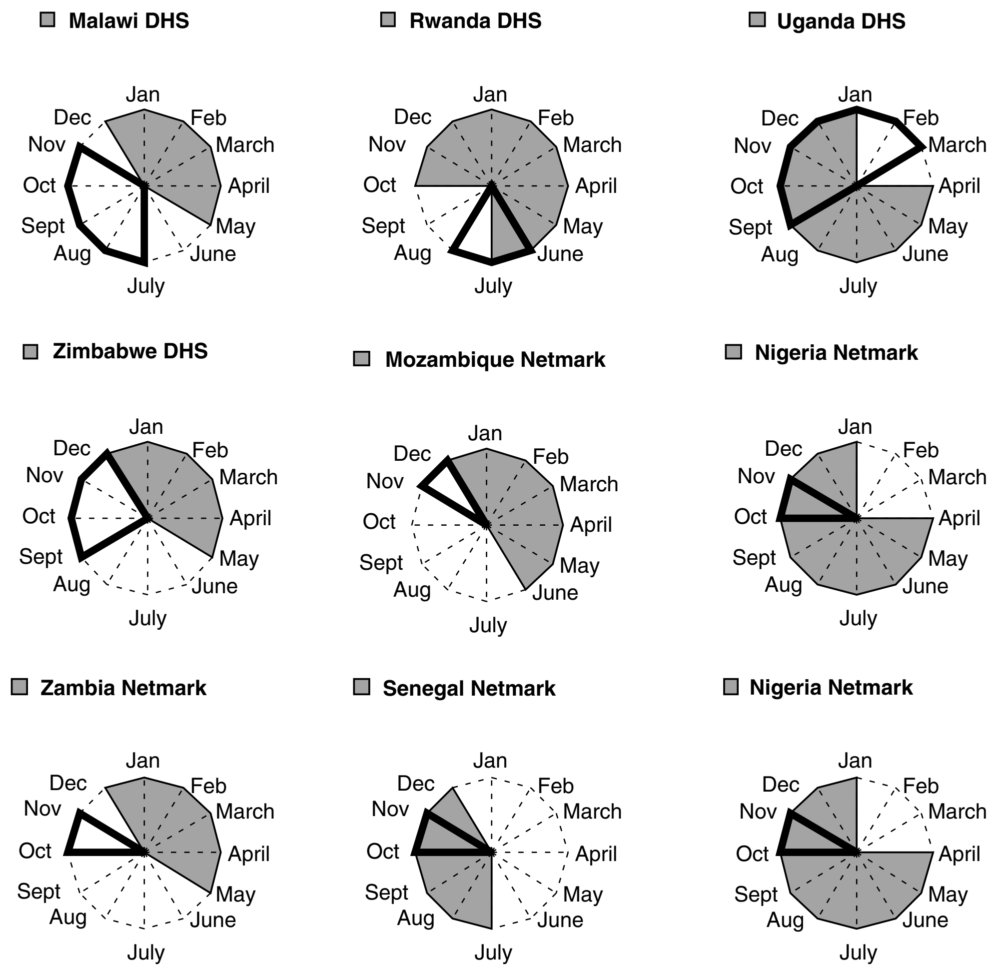

Figure 4 Diagrammatic illustration of malaria transmission season in comparison to timing of surveys, for typical districts in surveys with data available on net possession, net use and the timing of fieldwork. Shaded area represents the average malaria transmission season in the district (Tanser *et al.* 2003), the thick demarcation line indicates the survey period.

Table 2 Correctness of reported use of mosquito nets (ITN or untreated), based on surveys that visually inspected sleeping places in houses or that inquired about condition

Reference	Setting and sample	Finding
Holtz *et al.* (2002)	Blantyre, Malawi, 2000, 672 HH with 231 nets	12.8% of owners (rural 27%, urban 11%) reported that (untreated or treated) nets had holes larger than 2 cm in diameter
Van Bortel *et al.* (1996)	Programme on three hills, Burundi, ≥1994, 772 nets in 772 HH	28% (7–47) of identified nets were not hung; 25% (25–26) were incorrectly hung
Kachur *et al.* (1999)	Western Kenya, 1997, 40 HH with 54 nets	87% of ITNs observed ≥3 years after purchase were in fair or good condition, thanks to repairs
Chambon *et al.* (1997)	Three urban and three rural sites, Cameroon, 1994, 1189 HH with 1144 nets	ITNs found in good state: urban 51%, rural 30%. In one rural site 3 years after free ITN distribution, 49% of nets found back in HH, but 91% of these with holes and tears
Hamel *et al.* (2001)	Bungoma district, Kenya, 1986, 670 HH with children <5 years	81% of nets in good condition, 93% large enough for the sides to be tucked under a bed or mat

HH, household; ITN, insecticide-treated net.

higher in the rainy, cooler months than in the dry, hot season. The same finding has also been reported in intervention trials that actively promoted ITN use, in western Kenya and northern Ghana (Binka & Adongo 1997; Alaii *et al.* 2003). In these settings, the rainy months are the season with highest mosquito nuisance and malaria transmission; in a large part of Africa, however, malaria transmission is not limited to the rainy season (Craig *et al.* 1999) and continuous use of mosquito nets is desirable. In a survey in Ouagadougou, Burkina Faso, the lower use of nets during the warmer season even detrimental, as most malaria here occurs in the hotter months (Procacci *et al.* 1991). The seasonality in net use in areas of perennial malaria transmission highlights a need for education promoting year-round use. For monitoring, the implications include that 'use during the preceding night' can be compared across surveys (over time or between regions) only if these are conducted in the same season. In surveys such as DHS and MICS, which for logistic reasons are mostly undertaken in the dry season, this indicator will underestimate average use. From the seasonality perspective, it would be preferable to measure 'usual use' or 'use during the last malaria season'; however, those indicators are probably more prone to recall bias and over-reporting for reasons of social desirability, which are possibly more serious biases. For comparison between surveys conducted in different seasons, the possession indicator, which should vary less by season, may therefore be more appropriate.

The gap between reported and effective use is of equal concern. In the large-scale surveys, the state of the net and correctness of use are typically not inspected, but similar levels of incorrect use (10–50%) may be assumed. Correctness of use is especially critical for untreated nets, which provide exclusively the protection from physical separation from mosquitoes and not the protection from repellence and killing of the insects. But also for ITNs that have not recently been re-treated, the state of the net may influence efficacy. For ITNs, insecticide re-impregnation rates will become a critical component of the monitoring of long-term effective coverage with ITNs, deserving a separate review of forthcoming DHS and MICS data. Studies conducted so far, in the context of ITN trials or social marketing projects, indicate that nets are often not reimpregnated at all or are reimpregnated too infrequently (Chambon *et al.* 1997; Hamel *et al.* 2001; Holtz *et al.* 2002). Re-impregnation frequency will in addition be an important determinant of the relative cost-effectiveness of the so-called long-lasting ITNs that are currently under development.

In only two of the surveyed districts, Cotonou in Benin and Dar es Salaam in the United Republic of Tanzania, use of any nets by children under 5 years exceeded 60%, the targeted ITN coverage for Africa agreed under Roll Back Malaria. Use between 50% and 70% are in fact the level achieved in mosquito net intervention trials, in which nets are provided free of charge and in abundance (D'Alessandro *et al.* 1995a; Binka *et al.* 1996; Nevill *et al.* 1996; Habluetzel *et al.* 1997; Lengeler 2000). The 60% target for all populations at risk, in mainly rural areas, thus remains extremely ambitious. Our analysis suggests that there is scope for improvement through the promotion of correct and consistent use (including repairs) of existing nets for the vulnerable group of young children, as well as through better net access (including replacement of worn-out nets).

Given the available data and the features of the indicators possession and child use presented here, what further data should be collected for monitoring Roll Back Malaria? In view of the large gap between possession and child use and the seasonal variation in the latter, neither indicator alone suffices. As child use will continue to be measured in many countries every 5 years under DHS and MICS, rapid interim assessments focusing on net possession may yield the most useful additional information. The relevance of net possession data for estimating child protection might be improved if the number of nets per household could also be established, as suggested by the correlation between numbers of nets and use for children in Kampala (Kampala City Council 2002) and a similar finding on the Solomon Islands (Yohannes *et al.* 2000). Given the large discrepancy between the 60% target and current coverage levels, samples need not be large to identify meaningful progress. The assessments would ideally be repeated at intervals of 1–2 years in a set of sentinel districts in all malaria-endemic countries.

In conclusion, both indicators 'possession' and 'reported use' have their advantages and disadvantages for monitoring coverage with mosquito nets in Africa. In drawing inferences about use, the variation with season must be taken into account. In a typical household possessing nets, half the children will not be sleeping under these nets. Given that nets are often used incorrectly, either indicator will overestimate actual protection. However, measurement of net use and possession provide the best available means to track progress in coverage with this principal malaria intervention. Regular, district-level rapid assessments of household possession of nets should complement ongoing in-depth surveys.

Acknowledgements

We thank Brian Williams for statistical advice, Fred Arnold and Noureddine Abderrahim for assistance in analysis and description of DHS data, Marlies Craig and Mapping Malaria risk in Africa (MARA) for providing predictions of malaria transmission seasons, Albert Kilian for providing the report on the Kampala survey, Samuel Ochola and the Division of Malaria Control, Ministry of Health, Kenya, for providing the report on the Kenya Roll Back Malaria survey, and Christian Lengeler for comments on the study design and manuscript.

References

Agyepong IA & Manderson L (1999) Mosquito avoidance and bed net use in the Greater Accra Region, Ghana. *Journal of Biosocial Sciences* **31**, 79–92.

Alaii JA, Hawley WA, Kolczak MS *et al.* (2003) Factors effecting use of permethrin-treated bednets during a randomised-controlled trial in Western Kenya. *American Journal of Tropical Medicine and Hygiene* **68**, 149–160.

Binka FN & Adongo P (1997) Acceptability and use of insecticide impregnated bednets in northern Ghana. *Tropical Medicine and International Health* **2**, 499–507.

Binka FN, Kubaje A, Adjuik M *et al.* (1996) Impact of permethrin impregnated bednets on child mortality in Kassena-Nankana district, Ghana: a randomized controlled trial. *Tropical Medicine and International Health* **1**, 147–154.

Bradley AK, Greenwood BM, Greenwood AM *et al.* (1986) Bed-nets (mosquito-nets) and morbidity from malaria. *Lancet* **2**, 204–207.

Chambon R, Lemardeley P, Louis FJ, Foumane V & Louis JP (1997) [Knowledge, attitudes and practice of populations faced with culicidae nuisances: results of 6 surveys taken in Cameroon in 1994]. *Bulletin de la Societé de Pathologie Exotique* **90**, 364–369.

Clarke SE, Bogh C, Brown RC, Pinder M, Walraven GEL & Lindsay SW (2001) Do untreated bednets protect against malaria? *Transactions of the Royal Society of Tropical Medicine and Hygiene* **95**, 457–462.

Craig MH, Snow RW & le Sueur D (1999) A climate-based distribution model of malaria transmission in sub-Saharan Africa. *Parasitology Today* **15**, 105–111.

D'Alessandro U, Aikins MK, Langerock P, Bennett S & Greenwood BM (1994) Nationwide survey of bednet use in rural Gambia. *Bulletin of the World Health Organization* **72**, 391–394.

D'Alessandro U, Olaleye BO, McGuire W *et al.* (1995a) Mortality and morbidity from malaria in Gambian children after introduction of an impregnated bednet programme [see comments]. *Lancet* **345**, 479–483.

D'Alessandro U, Olaleye BO, McGuire W *et al.* (1995b) A comparison of the efficacy of insecticide-treated and untreated bed nets in preventing malaria in Gambian children. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **89**, 596–598.

Desfontaine M, Gelas H, Cabon H, Goghomou A, Kouka Bemba D & Carnevale P (1990) [Evaluation of practice and costs of vector control on a family level in Central Africa. II. Douala City (Cameroon), July 1988]. *Annales de la Societé Belge de Médicine Tropicale* **70**, 137–144.

Guyatt HL & Snow RW (2002) The cost of not treating bednets. *Trends in Parasitology* **18**, 12–16.

Habluetzel A, Diallo DA, Esposito F *et al.* (1997) Do insecticide-treated curtains reduce all-cause child mortality in Burkina Faso? *Tropical Medicine and International Health* **2**, 855–862.

Hamel MJ, Odhacha A, Roberts JM & Deming MS (2001) Malaria control in Bungoma district, Kenya: a survey of home treatment of children with fever, bednet use and attendance at antenatal clinics. *Bulletin of the World Health Organization* **79**, 1014–1023.

Holtz TH, Marum LH, Mkandala C *et al.* (2002) Insecticide-treated bednet use, anaemia, and malaria parasitaemia in Blantyre district, Malawi. *Tropical Medicine and International Health* **7**, 220–230.

Hutchinson MF, Nix HA, McMahan JP & Ord KD (1995) *Africa – a Topographic and Climatic Database (CD-ROM)*. Center for Resource and Environmental Studies, Australian University, Canberra.

Kachur SP, Phillips-Howard PA, Odhacha AM, Ruebush TK, Oloo AJ & Nahlen BL (1999) Maintenance and sustained use of insecticide-treated bednets and curtains three years after a controlled trial in western Kenya. *Tropical Medicine and International Health* **4**, 728–735.

Kampala City Council (2002) *Mosquito Net Coverage. Baseline Assessment in 5 Parishes of Kampala*. Kampala City Council, Kampala.

Lengeler C (2000) Insecticide treated bednets and curtains for malaria control (Cochrane Review). *Cochrane Database Syst Rev Issue 2: CD 000363*.

McAfee D, De Lil E, Nkejuwimye C & Nsengiyumva G (1997) *Rwanda prevention and impregnated mosquito net survey: report on knowledge, attitudes and practices research*. Population Services International, Kigali.

MARA (1995) Mapping Malaria Risk in Africa. http://www.mara.org.za.

Marchant T, Schellenberg JA, Edgar T *et al.* (2002) Socially marketed insecticide-treated nets improve malaria and anaemia in pregnancy in southern Tanzania. *Tropical Medicine and International Health* **7**, 149–158.

Netmark (2001) Netmark baseline survey on insecticide-treated materials (ITMs): cross-national summary of findings. Netmark, a regional partnership for sustainable malaria prevention. http://www.netmarkafrica.org/research/quantitative/CrossCountryQuan2001.pdf.

Nevill CG, Some ES, Mung'ala VO *et al.* (1996) Insecticide-treated bednets reduce mortality and severe morbidity from malaria among children on the Kenyan coast. *Tropical Medicine and International Health* **1**, 139–146.

Nuwaha F (2001) Factors influencing the use of bed nets in Mbarara municipality of Uganda. *American Journal of Tropical Medicine and Hygiene* **65**, 877–882.

Ochola SA & Snow RW (2002) *Analysis of Community-based Baseline Survey of Roll Back Malaria Indicators in Four Sentinel Districts*. Division of Malaria Control, Ministry of Health, Kenya.

Okrah J (2002) Community factors associated with malaria prevention by mosquito nets: an exploratory study in rural Burkina Faso. *Tropical Medicine and International Health* **7**, 240–248.

ORC Macro/Measure DHS *Demographic and Health Surveys (DHS)*. ORC Macro, Calverton, MD. http://measuredhs.com.

Procacci PG, Lamizana L, Pietra V, Di Russo C & Rotigliano G (1991) [Use of permethrin-impregnated curtains by the inhabitants of a rural community in Burkina Faso]. *Parassitologia* **33**, 93–98.

Roll Back Malaria (2000a) *The African summit on Roll Back Malaria*. World Health Organization, Abuja. WHO/CDS/RBM/2000.17.

Roll Back Malaria (2000b) *Framework for Monitoring Progress and Evaluating Outcomes and Impact*. World Health Organization, Geneva. WHO/CDS/RBM/2000.25.

Stallworthy G (1997) *Social Marketing of Impregnated Mosquito Nets in Mashonaland Central, Zimbabwe*. Population Services International, Harare.

Tanser FC, Sharp BL & le Sueur D (2003) Malaria seasonality and the potential impact of climate change in Africa. (in press).

UNICEF (2001) *Multiple Indicator Cluster Surveys (MICS-2)/ End of Decade Assessment*. http://www.childinfo.org/MICS2/.

Van Bortel W, Barutwanayo M, Delacollette C & Coosemans M (1996) Motivation à l'acquisition et à l'utilization des mostiquaires imprégnées dans une zone à paludisme stable au Burundi. *Tropical Medicine and International Health* **1**, 71–80.

World Bank (2003) *Living Standard Measurement Surveys (LSMS)*. http://www.worldbank.org/lsms/.

Yohannes K, Dulhunty JM, Kourleoutov C *et al.* (2000) Malaria control in central Malaita, Solomon Islands. 1. The use of insecticide-impregnated bed nets. *Acta Tropica* **75**, 173–183.

Authors

All authors at WHO, Communicable Diseases, 1211 Geneva 27, Switzerland.

Dr Eline L. Korenromp, Tel.: +41 22 791 1378/1329; Fax: +41 22 791 4824; E-mail: korenrompe@who.int (corresponding author).

John Miller, Tel.: +41 22 791 3620; Fax: +41 22 791 4824; E-mail: millerj@who.int

Dr Richard E. Cibulskis, Tel.: +41 22 791 2731; Fax: +41 22 791 4824; E-mail: cibulskisr@who.int; current address: DFID (Malawi), British High Commission, P.O. Box 30042, Lilongwe 3, Malawi, Tel.: +265 01 772 400 ext. 2240; E-mail: r_cibulskis@dfid.gov.uk

Dr M. Kabir Cham, Tel.: +41 22 791 3842; Fax: +41 22 791 4824; E-mail chamm@who.int

Dr David Alnwick, Tel.: +41 22 791 2769; Fax: +41 22 791 4824; E-mail alnwickd@who.int

Dr Christopher Dye, Tel.: +41 22 791 2904/4566, Fax: +41 22 791 4268; E-mail: dyec@who.int

Appendix

Least-squares linear regression of mosquito net use (in percentage of children under 5 years who slept under the net the preceding night) on household possession (in percentage of households possessing at least one net) and country in Africa. All surveys or surveyed sub-country regions were weighted equally.

Any nets

Model 1 Covariate:possession; fixed factor: intercept (simplification: ignoring inter-country variation, corresponding to Figure 1)

	Parameter estimate (SE)	Significance
Intercept	−4.235 (1.16)	0.000*
Possession	0.875 (0.037)	0.000*

Number of observations, 69; degrees of freedom in model, 2; $R^2 = 0.892$.
* Significant parameters.
SE, standard error.

Model 2 Covariate:possession; fixed factors: country, intercept

	Parameter estimate (SE)	Significance
Intercept	−5.74 (1.51)	0.000*
Possession	0.86 (0.043)	0.000*
Country = Benin (eight regions)	5.43 (2.58)	0.040
Country = Gambia (national)	−2.09 (5.21)	0.690
Country = Kenya (five districts)	−2.39 (2.58)	0.357
Country = Malawi (three regions)	1.90 (3.02)	0.532
Country = Mozambique [urban rural (five sites pooled)]	−4.65 (3.62)	0.204
Country = Nigeria urban rural (five sites pooled)	4.27 (3.54)	0.233
Country = Rwanda (six regions)	6.21 (2.36)	0.011*
Country = Senegal [urban rural (five sites pooled)]	-5.64 (3.67)	0.130
Country = Tanzania (22 districts)	3.21 (2.00)	0.113
Country = Uganda (six regions)	1.75 (2.40)	0.469
Country = Zambia [urban rural (five sites pooled)]	−4.94 (3.62)	0.178
Country = Zimbabwe (10 regions)	0 (reference category)	

Number of observations, 69; degrees of freedom in model, 13; $R^2 = 0.932$.
* Significant parameters.
SE, standard error.

ITNs

Model Covariate: possession. Corresponds to Figure 1; intercept and country omitted because not significant

	Parameter estimate (SE)	Significance
Possession	0.547 (0.025)	0.000*

Number of observations, 14; degrees of freedom in model, 1; $R^2 = 0.974$.
* Significant parameters.
SE, standard error.