Which delivery systems reach the poor? A review of equity of coverage of ever-treated nets, never-treated nets, and immunisation to reduce child mortality in Africa

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Insecticide-treated nets (ITNs) and childhood vaccination are two of the most powerful interventions available to prevent childhood mortality in Africa, but ITN coverage is still very low. Current debates about how to increase ITN coverage are concerned with the roles of different supply and delivery systems, in particular whether or not commercial net markets have any useful role. Here, we review data available on coverage and equity of coverage of three interventions to prevent childhood mortality. We compiled and analysed data from nationally representative surveys in 26 African countries to compare equity of coverage of (1) the Expanded Programme on Immunisation (EPI), (2) any net, (3) ever-treated nets (ie, ITNs), and (4) never-treated nets (ie, untreated nets; UTNs). We assumed that ever-treated net coverage mostly reflects the activities of public-health programmes and projects, and that never-treated net coverage mostly reflects the activity of local unsubsidised commercial markets. We discuss the validity, limitations, and possible biases of these assumptions. We estimate that 87% of the 8·4 million children protected by nets used UTNs. We used the concentration index (CI) to assess equity of coverage of the interventions. The data shows that never-treated net coverage is surprisingly equitable: overall, and despite substantial regional variations, it is comparable in equity to EPI (median CI_{UTN}=0·166, CI_{EPI}=0·075; p=0·3). In almost all countries, coverage of ITNs is strongly concentrated in the least poor households, and significantly more inequitable than both UTNs (median CI_{ITN}=0·435, mean CI_{UTN}=0·158; p<0·001) and EPI (median CI_{ITN}=0·435, CI_{EPI}=0·075; p<0·001). These results suggest that the public-health value of commercial net markets has been greatly underestimated, and that these markets have so far contributed more to equitable and sustainable coverage of mosquito nets, and hence to the prevention of malaria in Africa, than have the ITNs delivered by public-health systems and projects.

Lancet Infect Dis 2005; 5: 709–17

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Introduction

In the poorer countries of the world, a large proportion of child mortality is caused by a few preventable diseases. Effective interventions against these diseases exist,[1] but the Millennium Development Goal of reducing child mortality by two-thirds by the year 2015 will not be achieved unless there is a massive increase in the coverage of these interventions,[2] especially in the poorest and most vulnerable groups.[3]

Two of the most powerful preventive interventions against child mortality in Africa are insecticide-treated nets (ITNs) and childhood immunisation. During the 1970s and 1980s, greatly improved immunisation rates were achieved by the Expanded Programme on Immunisation (EPI). Although coverage rates have been declining recently in some countries, particularly poor countries,[2] EPI is still justifiably regarded as a public-health success story.

Strategies for increasing ITN coverage, by contrast, are a relatively recent development, and are still the subject of active debate. There is general agreement that subsidised access to ITNs should be provided on a large scale and in the long term, but disagreement exists over how these subsidies should be deployed. A central issue in this debate is the actual and potential contribution of unsubsidised commercial markets, including existing local markets in untreated nets (UTNs), and whether or not these markets should be included in the design of systems for delivering subsidies.

Some experts doubt the capacity of public-health delivery systems on their own to achieve full ITN coverage throughout Africa, and the capacity of donor financing to sustain this goal. The net coverage achieved by existing commercial markets is potentially valuable, because it provides public-health benefits in a sustainable way and at no public cost, thereby freeing public money for other vital interventions such as treatment with effective antimalarial drugs. A mixed strategy could therefore be proposed in which there is the maximum possible level of subsidised provision targeted to the economically or biologically vulnerable, but the system used to deploy these subsidies is designed to preserve, and where possible to encourage, existing commercial net markets.[4] For example, current programmes are testing the use of vouchers that allow recipients (eg, pregnant women attending antenatal clinics) to buy ITNs at a heavily subsidised price from commercial retail sources.

Other experts believe that ITNs should be provided free of charge to everyone at risk in Africa using donor funding.[5] They are sceptical about the value and potential of commercial markets, which they see as serving mainly the urban rich, and as contributing little towards protection of the rural poor who suffer most from malaria. Instead, they argue that ITNs are of comparable cost-effectiveness to EPI vaccinations and they should be delivered in the same way: free of charge through the public sector.[5]

Since people have to pay for nets supplied through unsubsidised commercial markets, but not for EPI vaccinations, it is reasonable to expect EPI coverage to be more equitable—that is, more equally distributed among richer and poorer households—than commercial net coverage. However, remarkably little is known about commercial net markets in Africa and the pattern of net coverage that they support. The assertion that these markets do not serve the rural poor has not been supported by large-scale quantitative data on coverage. We attempt to fill this gap in the evidence.

Our starting point was the data on net coverage in 28 countries published in the WHO's *Africa malaria report*.[6] According to the report, the number of children under the age of 5 years sleeping under an ITN was seven times lower than the number sleeping under any kind of net. This finding was surprising, because public-health programmes and projects generally distribute ITNs, and very rarely distribute nets without insecticide. Moreover in most African countries, public-health programmes are the only important and large-scale sources of ITNs, and the nets made by local suppliers are almost all untreated. The treatment history of an individual net—whether or not it has ever been treated—therefore gives information about its source. We based our analysis on the assumption that most of the ITNs reported in these surveys were originally supplied by a public-health programme or project, while most of the UTNs were bought at unsubsidised prices from local commercial suppliers. We collated data from recent nationally representative surveys in Africa, and analysed the information on coverage of children with nets (treated and untreated) and with immunisation. In particular, we tried to test two hypotheses. First, that public-health programmes and projects, which in the past have mostly sold imported ITNs at subsidised prices, have achieved more equitable net coverage than local commercial net suppliers and traders, which mostly sell UTNs at unsubsidised prices. Second, that the coverage produced by these local commercial markets in UTNs is also less equitable than that of EPI, which is delivered free of charge.

Methods

Data on national coverage from demographic and health surveys and multiple-indicator cluster surveys were extracted from their respective websites.[7,8] Demographic and health surveys and multiple-indicator cluster surveys are nationally representative household surveys in which questions are asked of women and the children for whom they are caretakers. Data are collected at the household level on all children under the age of 5 years. Our analysis focused on coverage of young children with (1) immunisation (ie, via EPI), (2) any net, (3) ever-treated nets (ie, ITNs), and (4) never-treated nets (ie, UTNs). We defined immunisation coverage as the proportion of children aged 12–23 months fully vaccinated against the six EPI target diseases, as recorded on a health card or reported by the mother. We defined any-net coverage as the proportion of children under 5 years who slept under any mosquito net (treated or untreated) the night preceding the survey. Ever-treated net coverage was defined as the proportion of children under 5 years of age who slept the previous night under a net that had previously been treated with insecticide. This definition includes all nets that had ever been treated, and is not restricted to nets that had been treated in the previous 6–12 months. Never-treated net coverage was defined as the proportion of children under the age of 5 years who slept under a net that had never been treated with insecticide. Since most databases report the treatment history of the nets used by individual children, never-treated net coverage could be inferred by subtracting ever-treated net coverage from any-net coverage. This estimation was not possible in the cases of Ethiopia, Mali, Tanzania, and Zimbabwe, because these databases record net use by children at the household level but not by individual children. For these datasets, we estimated ever-treated and never-treated net coverage by assuming that if a household contained both an ever-treated net and a child under the age of 5 years, then the ever-treated net was used by that child. This assumption will most likely overestimate ever-treated net coverage and underestimate never-treated net coverage, and is therefore conservative for the purposes of this paper.

Data were obtained on 26 countries (28 surveys) in sub-Saharan Africa, from 18 multiple-indicator cluster surveys and ten demographic and health surveys undertaken between 1999 and 2003. Of the 28 databases included in the analysis, data were available on immunisation coverage in 27 countries, any-net coverage in 28, and ever-treated net coverage in 26. Among the datasets with information on individual children, the median number of children in the dataset was 5597 (range 2234–23 369). For the four demographic and health surveys where coverage is reported at the household level, the median number of households sampled was 9350 (range 3615–14 072). These datasets constitute the most current nationally representative data; however, they may underestimate coverage in countries where scaling-up of ITN programmes is more recent.

We calculated that among the 23 countries with reliable population data, with a total population of approximately 78 million children under the age of 5 years, 7·3 million of these children were covered by UTNs, and 1·1 million by ITNs during the period 1999–2003. Since these are "ever-treated" ITNs, it is likely that only a small fraction of them had been treated in the past year.

Both demographic and health surveys and multiple-indicator cluster surveys use asset indices as a proxy measure of socioeconomic status,[9] and can therefore be used to compare levels of health indicators with economic status.[10] Questions are asked on a range of household assets and housing characteristics. Principal components analysis is used to weight the assets and build a socioeconomic index by which households are ranked and divided into quintiles. This method has been validated in other surveys with information on both assets and income or expenditure.[11] We considered three ways of using these socioeconomic quintiles to examine equity of coverage of each intervention: the equity ratio, the equity difference, and the concentration index (CI).[12] We selected the CI, which measures the degree to which a household characteristic is concentrated in richer (or poorer) households, across all quintiles. The equity ratio and equity difference compare coverage in only the highest and lowest quintiles, thereby excluding 60% of the data. Households are ranked by socioeconomic status, and the cumulative percentage of households with the characteristic is plotted against the cumulative percentage of all households (figure 1). If the characteristic is equally distributed among all socioeconomic status levels, the result is a 45° straight line—the line of equity; otherwise, it is a curve known as the concentration curve, which is concave if the characteristic is concentrated in richer households or convex if it is concentrated in poorer ones. The CI is defined as twice the area between the concentration curve and the line of equity.[13] A CI of 0 is indicative of perfect equity, –1 the highest degree of pro-poor inequity, and +1 the highest degree of pro-rich inequity. The CI provides a measure of equity across all five quintiles that is relatively independent of the overall level of coverage (higher coverage does not necessarily entail less inequality[14]), and was our method of choice for this analysis.

We calculated the CI from the pre-grouped data, using the formula:[15]

$$CI=(p_1L_2 - p_2L_1) + (p_2L_3 - p_3L_2) + \ldots + (p_{t-1}L_t - p_tL_{t-1})$$

Where p_t is the cumulative percentage of children in the t^{th} quintile (from poorest to richest), and L_t is the cumulative percentage of children covered by the intervention in the t^{th} quintile.

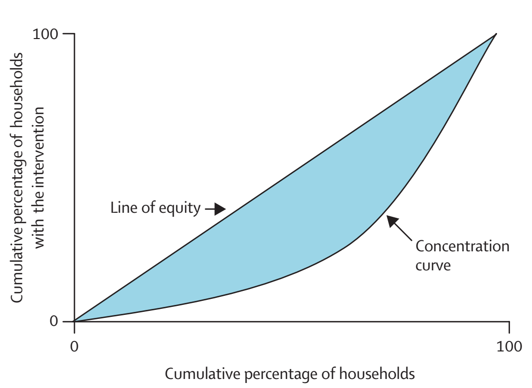

Figure 1: **Diagram illustrating the use of the concentration index as a measure of equity**
CI=twice the area between the line of equity and the concentration curve.

Standard errors and confidence intervals for the concentration indices were calculated using the spreadsheet developed by the World Bank based upon the formula by Kakwani and colleagues[16] for grouped data. Comparisons of the equity of coverage between interventions were made using Wilcoxon signed rank test. Spearman's correlation coefficients were used to measure the relation between coverage and equity.

Results

The data on intervention coverage are presented in figure 2. Each of the charts represents one country dataset, and shows the percentage coverage for each intervention, by socioeconomic quintile, within that country. Summary statistics on overall coverage and CI are presented in table 1.

There was considerable variation across countries in the coverage of all interventions. In general, EPI coverage was much higher (median 48%, range 13–78%) than any-net coverage (median 15%, range 1–67%); any-net coverage was higher than EPI coverage only in Chad, Mali, and Guinea Bissau. At the time of these surveys, none of the countries studied was meeting the global target of more than 80% EPI coverage,[17] although in previous rounds of demographic and health surveys, both Malawi (1996) and Zimbabwe (1994) had achieved this target by a narrow margin.

Ever-treated net coverage levels were far below the Abuja target of 60%.[18] The three countries with the highest ever-treated net coverage levels were all small countries: Sao Tome (22%), The Gambia (14%), and Comoros (9%). Never-treated net coverage was generally higher than ever-treated coverage: only in Rwanda and Sao Tome were children more likely to be sleeping under an ITN than an untreated one. In one country, Guinea Bissau, 67% of children under 5 years were sleeping under a mosquito net; but only 7% were sleeping under ITNs. Of the seven countries with high any-net coverage (defined as >30%), four are "small nations" (population less than 1·5 million). Mali and Madagascar stand out as the only two countries with sizeable populations that have net coverage levels that are both high and equitable.

When the equity of any-net coverage is considered, as well as the overall level of coverage, some conspicuous sub-regional patterns can be seen in the country data. The country charts showing higher and more equitable any-net coverage—ie, those appearing in the right-hand column, and at the top of the middle column in figure 2— mostly represent countries in west Africa, central Africa and the Sahel. Conversely, the countries with less equitable and lower any-net coverage (ie, those at the bottom and to the left of figure 2) mostly belong to east and southern Africa. Exceptions include Uganda,

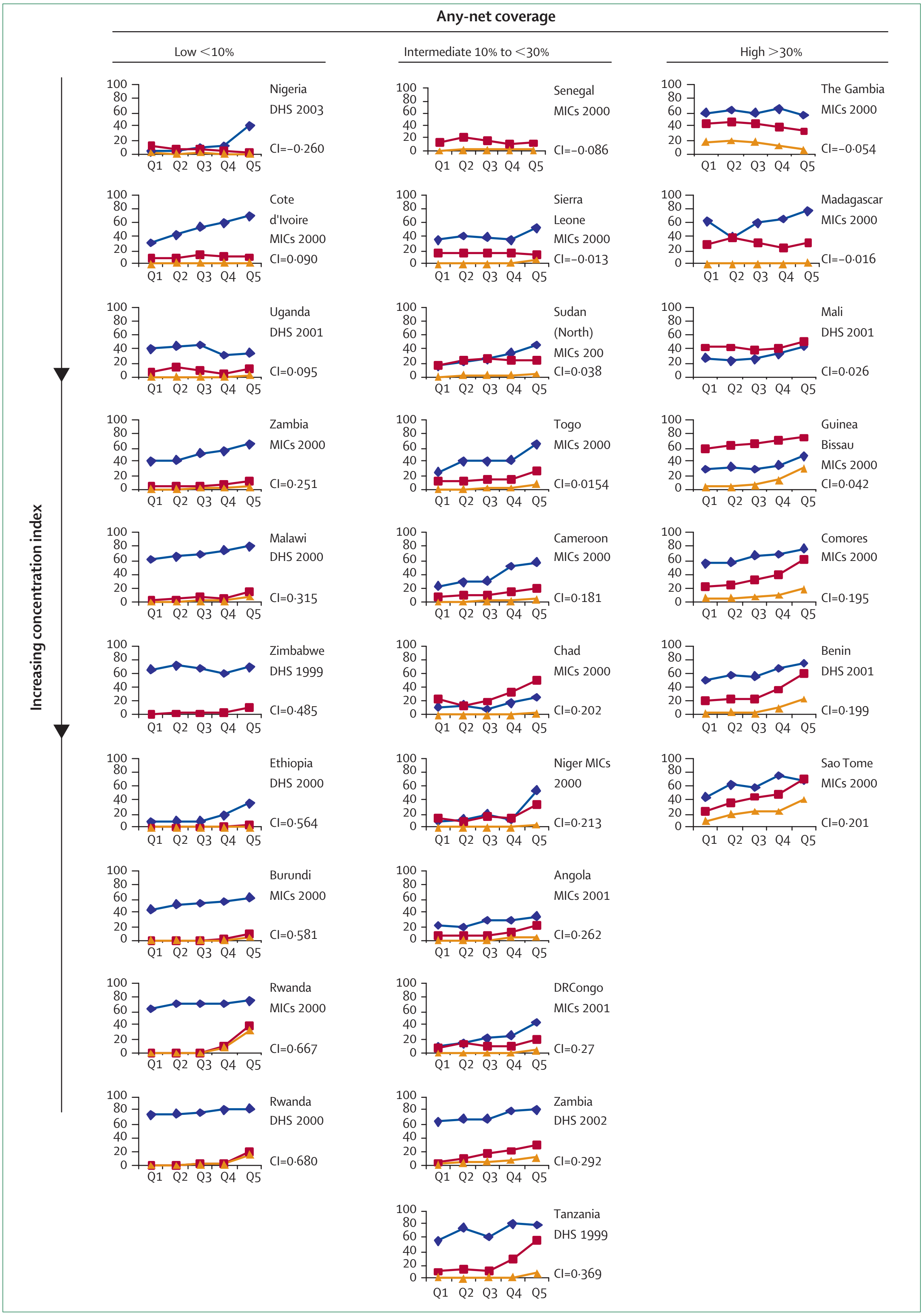

Figure 2: **Coverage by quintile of any nets, insecticide-treated nets, and the EPI by country**

Each of the 28 small charts represent the data from one African country, showing coverage of EPI (diamonds), the proportion of children under the age of 5 years sleeping under any net (squares), and the proportion of children sleeping under an ITN (triangles). Coverage is shown as a simple percentage (y axis) across socioeconomic quintiles (x axis) from the poorest (Q1) to the least poor (Q5). A horizontal line indicates equal coverage across quintiles and hence equity. If the line slopes upwards from Q1 to Q5, there is inequity biased towards the least poor (eg, any-net coverage in Tanzania); a downward sloping line indicates inequity biased towards the poorest (eg, any-net coverage in The Gambia). Charts are arranged in columns according to the overall level of any-net coverage (arbitrarily categorised as relatively low, intermediate, relatively high), and are ordered within columns so that countries with more equitable or pro-poor net coverage are at the top of each column, while those with inequitable coverage are at the bottom. DHS=demographic and health surveys; CI=concentration index (referring here specifically to that on “any net”); MICs=multiple-indicator cluster surveys.

	Immunisation			Any net			Ever-treated nets			Never-treated nets		
	National coverage (%)	CI	95% confidence interval	National coverage (%)	CI	95% confidence interval	National coverage (%)	CI	95% confidence interval	National coverage (%)	CI coverage	95% confidence interval
Angola (MICs 2001)	27	0·116	0·061 to 0·171	10	0·262	0·160 to 0·364	2	0·379	0·252 to 0·506	8	0·228	0·083 to 0·373
Benin (DHS 2001)	61	0·075	0·037 to 0·113	31	0·199	0·073 to 0·324	7	0·467	0·333 to 0·602	24	0·118	0·047 to 0·189
Burundi (MICs 2000)	54	0·055	0·014 to 0·096	3	0·581	0·426 to 0·736	1	0·597	0·405 to 0·789	1	0·557	0·353 to 0·761
Cameroon (MICs 2000)	36	0·192	0·139 to 0·245	11	0·181	0·103 to 0·259	1	0·430	0·261 to 0·599	10	0·149	0·059 to 0·239
Chad (MICs 2000)	15	0·164	0·050 to 0·278	27	0·202	0·063 to 0·341	1	0·377	0·007 to 0·747	26	0·199	0·066 to 0·332
Comores (MICs 2000)	66	0·067	0·036 to 0·098	36	0·195	0·121 to 0·269	9	0·278	0·153 to 0·403	27	0·166	0·113 to 0·219
Cote d'Ivoire (MICs 2000)	48	0·151	0·078 to 0·224	10	0·090	0·010 to 0·170	1	0·260	0·029 to 0·491	9	0·068	–0·016 to 0·152
DR Congo (MICs 2001)	23	0·277	0·165 to 0·389	12	0·270	0·082 to 0·458	1	0·684	0·490 to 0·878	11	0·080	–0·075 to 0·235
Ethiopia (DHS 2000)	14	0·319	0·245 to 0·393	1	0·564	0·366 to 0·762	<1	0·615	0·305 to 0·925	1	0·558	0·368 to 0·748
The Gambia (MICs 2000)	62	–0·008	–0·039 to 0·023	42	–0·054	–0·103 to –0·005	15	–0·143	–0·298 to 0·012	27	0·001	–0·030 to 0·032
Guinea Bissau (MICs 2000)	34	0·085	–0·001 to 0·171	67	0·042	0·026 to 0·058	7	0·459	0·341 to 0·577	59	–0·030	–0·095 to 0·035
Madagascar (MICs 2000)	58	0·046	–0·048 to 0·140	30	–0·016	–0·100 to 0·068	1	0·050	–0·050 to 0·150	30	–0·017	–0·103 to 0·069
Malawi (DHS 2000)	71	0·052	0·034 to 0·070	7	0·315	0·142 to 0·488	3	0·477	0·314 to 0·639	4	0·217	0·054 to 0·379
Mali (DHS 2001)	30	0·109	0·025 to 0·193	42	0·026	–0·026 to 0·078	..	..	..	..	..	0·000 to 0·000
Niger (MICs 2000)	22	0·339	0·163 to –0·515	17	0·213	0·054 to 0·372	1	0·534	0·414 to 0·654	16	0·193	0·046 to 0·340
Nigeria (DHS 2003)	13	0·476	0·349 to 0·603	6	–0·260	–0·366 to –0·153	1	–0·248	–0·463 to –0·032	5	–0·263	–0·361 to –0·165
Rwanda (DHS 2000)	78	0·025	0·015 to 0·035	5	0·680	0·545 to 0·814	4	0·678	0·524 to 0·831	1	0·687	0·551 to 0·824
Rwanda (MICs 2000)	70	0·025	0·000 to 0·050	6	0·667	0·420 to 0·914	5	0·692	0·431 to 0·953	1	0·543	0·259 to 0·827
SaoTome and Principe (MICs 2000)	66	0·017	–0·042 to 0·076	43	0·201	0·095 to 0·307	23	0·219	0·064 to 0·374	20	0·181	0·122 to 0·240
Senegal (MICs 2000)	..	..	..	15	–0·086	–0·596 to 0·424	2	0·020	–0·239 to 0·279	14	–0·098	–0·161 to –0·035
Sierra Leone (MICs 2000)	39	0·057	–0·029 to 0·143	15	–0·013	–0·025 to –0·001	2	0·580	0·427 to 0·733	14	–0·078	–0·160 to 0·004
Sudan (north) (MICs 2000)	29	0·192	0·112 to 0·272	23	0·038	–0·035 to 0·111	2	0·268	0·115 to 0·421	21	0·018	–0·084 to 0·120
Tanzania (DHS 1999)	69	0·064	0·021 to 0·107	23	0·369	0·269 to 0·469	2	0·451	0·293 to 0·609	21	0·359	0·259 to 0·459
Togo (MICs 2000)	41	0·159	0·039 to 0·279	15	0·154	0·031 to 0·277	2	0·469	0·287 to 0·651	13	0·106	–0·070 to 0·282
Uganda (DHS 2001)	38	–0·057	–0·082 to –0·033	9	0·095	–0·095 to 0·285	1	0·257	–0·078 to 0·592	9	0·007	–0·220 to 0·233
Zambia (DHS 2002)	71	0·048	0·025 to 0·071	16	0·292	0·124 to 0·460	6	0·296	0·134 to 0·458	10	0·290	0·089 to 0·490
Zambia (MICs 2000)	51	0·095	0·060 to 0·130	6	0·251	0·163 to 0·339	1	0·435	0·212 to 0·658	5	0·211	0·123 to 0·299
Zimbabwe (DHS 1999)	67	–0·007	–0·032 to 0·018	3	0·485	0·264 to 0·706	..	..	..	..	..	..

CI=concentration index; DHS=demographic and health survey; MICs=multiple-indicator cluster surveys

Table 1: **Coverage and equity of coverage of EPI, any net, ever-treated, and never-treated nets**

where any-net coverage is low but equitable, and Madagascar, where the pattern of net coverage is quite different from its eastern and southern African neighbours, and is closer to that seen in the Sahelian countries of west Africa.

Comparing equity between interventions, there was no significant difference between the overall median CIs for EPI and UTNs (p=0·3, table 2). However, this overall comparison conceals some sub-regional variations. EPI coverage was more equitable (measured as a lower CI—ie, $CI_{EPI}<CI_{UTN}$) than UTN coverage in 13 countries, of which ten are in east and southern Africa. Conversely, never-treated net coverage was more equitable than EPI coverage ($CI_{UTN}<CI_{EPI}$) in ten countries, of which nine are in west, central, and Sahelian Africa. Within the group of east and southern African countries, the median CI_{EPI} was significantly lower than the median CI_{UTN} (p=0·002), and in the west, central, and Sahelian group, the median CI_{EPI} was higher than the median CI_{UTN} (p=0·04).

Ever-treated net coverage was not only lower, but was also much more inequitable, than either EPI or UTNs. Ever-treated net coverage was less equitable than EPI coverage ($CI_{ITN}>CI_{EPI}$) in 21 countries, and more equitable ($CI_{ITN}<CI_{EPI}$) in only two. These two were The Gambia, where ever-treated net coverage is unusually high, and Nigeria, where it is unusually low. Similarly, ever-treated net coverage was less equitable than never-

	Sub-Saharan Africa			East and southern Africa			West, central, and Sahelian Africa		
	Surveys	Median CI	p*	Surveys	Median CI	p*	Surveys	Median CI	p*
EPI	25	0·075	0·3	12	0·054	0·003	13	0·159	0·04
UTN		0·166	..		0·259	..		0·080	..
EPI	25	0·075	<0·001	12	0·054	0·002	13	0·159	0·04
ITN		0·435	..		0·443	..		0·430	..
ITN	26	0·433	<0·001	12	0·443	0·004	14	0·404	0·002
UTN		0·158	..		0·259	..		0·074	..

*p values were obtained using Wilcoxon signed rank test. CI=concentration index; EPI=expanded programme on immunisation; ITN=insecticide-treated net; UTN=untreated net.

Table 2: **Comparisons of equity of coverage between EPI versus UTNs,EPI versus ITNs, and ITNs versus UTNs**

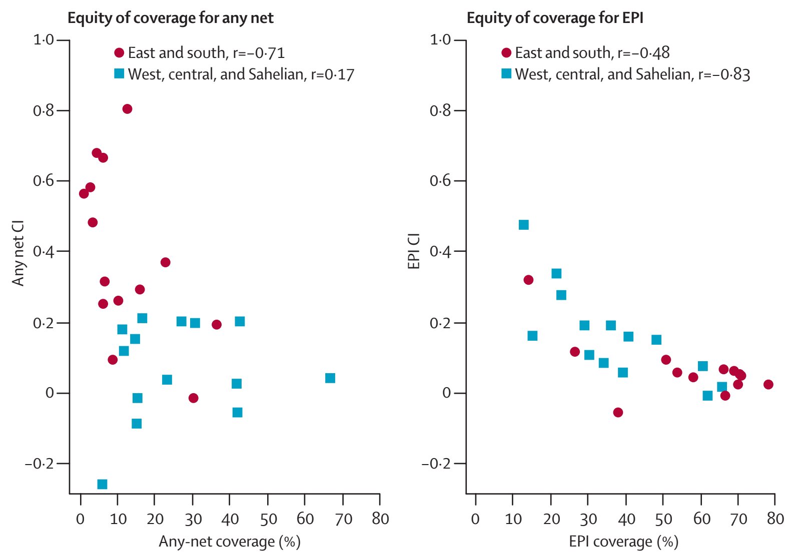

Figure 3: **Concentration index by proportion of children under 5 years who slept under any net the night preceding the survey in west, central, and Sahelian African countries, and in east and southern African countries**

treated net coverage ($CI_{ITN}>CI_{UTN}$) in 23 countries, and more equitable ($CI_{ITN}<CI_{UTN}$) in only two. In this case, the two exceptions were The Gambia and Rwanda, both being countries where a large proportion of all nets are treated. In some countries, equity of coverage of ITNs was sometimes markedly more inequitable than that of UTNs—eg, Republic of Congo, $CI_{ITN}=0 \cdot 68$ and $CI_{UTN}=0 \cdot 08$. The overall median CI for ITNs was much higher than that for either EPI or UTNs, and these differences were highly statistically significant ($p<0 \cdot 001$ in each case).

For both EPI and any-net coverage, there was an association between overall coverage and equity, with equity (measured as a lower CI) tending to improve as coverage increases (figure 3). This relation was stronger in the case of EPI ($r=-0 \cdot 78$, $p<0 \cdot 001$) than for any-net coverage ($r=-0 \cdot 49$, $p=0 \cdot 01$). Sub-regionally, the relation between any-net coverage and equity was strong among countries of east and southern Africa ($r=-0 \cdot 71$ $p=0 \cdot 01$) but weak among west, central, and Sahelian Africa countries ($r=0 \cdot 17$, $p=0 \cdot 2$). By contrast, for EPI, the relation between coverage and equity was stronger among west, central, and Sahelian Africa countries ($r=-0 \cdot 83$, $p<0 \cdot 001$) than among countries of east and southern Africa ($r=-0 \cdot 48$, $p=0 \cdot 1$).

Discussion

The data indicate that in the surveyed countries 87% of the nets covering young children have never been treated with insecticide. Our analysis strongly contradicts our first hypothesis, that the delivery of ITNs by subsidised programmes is more equitable than the delivery of UTNs by unsubsidised commercial markets. In fact, ever-treated net coverage was strongly biased towards richer households in almost all countries, wherease never-treated net coverage was generally much more equitable, especially in west, central, and Sahelian Africa.

When these surveys were done, it was more common for ITN projects (non-governmental organisations) and programmes (the public sector) to sell ITNs at subsidised prices than to give them away free of charge. Therefore, our study does not indicate what would happen if free ITN delivery campaigns were greatly expanded, but it does provide useful evidence as to what happens when projects sell ITNs. The price at which ITNs have been sold by projects has usually been set at a level below that of unsubsidised nets in local shops, partly to ensure that poor people have better access to ITNs as a result of the project. This approach is also most commonly used in social marketing projects. Very few such projects have delivered UTNs, and in many cases they created new delivery channels rather than using those through which unsubsidised and UTNs were being sold before the project began. Our analysis suggests that this strategy of subsidised selling has not, as a general rule, been effective as a means of improving equity of access. It seems that in practice, richer (or less poor) people have been more successful than the poorest in taking advantage of subsidised supplies.[19] However, it is important to take into account the dates of the surveys presented in this analysis since some of the projects currently scaling-up ITN delivery were not substantial contributors to the coverage measured at the time of these surveys.

Our findings imply that the existence of a local net factory is not a prerequisite for high commercial net coverage. There are no factories making nets or netting in the two larger countries with exceptionally high and equitable net coverage levels, Mali and Madagascar. In Mali, where 54% of households own one or more nets, there are two main types of manufactured net: those that have been delivered by projects in some regions, and relatively flimsy commercial nets imported from Thailand (B52 brand). Most nets, however, are locally stitched from a wide variety of fabrics, by small family businesses. A recent household survey carried out by the NetMark project[20] distinguished between “tailor-made” nets and “manufactured” nets. It found that manufactured nets were mainly owned by the richest households, while in the poorest quintile, tailor-made nets outnumbered manufactured nets by a ratio of more than four to one. The same pattern of supply, dominated by small businesses stitching nets from a variety of materials, also exists in most of the rest of west, central, and Sahelian Africa. By contrast, most of the nets in east Africa are factory produced, and much less diverse than those in west Africa. The findings therefore suggest that a diversity of supply may be a factor favouring high coverage.

The evidence is mixed with regard to our second hypothesis. This hypothesis postulated that EPI systems, which deliver vaccination free of charge, are expected to achieve more equitable coverage than commercial net delivery systems, which sell UTNs at unsubsidised prices. In most countries of east and southern Africa, the data do provide evidence to support this hypothesis. The data from west, central, and Sahelian Africa, however, point in the opposite direction, and suggest that never-treated net coverage is more equitable than EPI coverage in most of this sub-region. The need for drastic improvement in delivery of EPI immunisation is indicated by very low coverage in some countries—eg, Chad (15%), Niger (21%), and Nigeria (12%).

We assumed that treatment history gives information on the probable source of a net, and it is important to examine critically the possible biases that could arise from this assumption. There are two levels of possible misclassification bias, the treatment status of the net and the source of the net, which are linked within our assumption. In terms of misclassifying the treatment status, some owners of project ITNs may be unaware that their net has ever been treated, causing an ITN to be misclassified as never treated, and therefore a project net to be misclassified as commercial. We are not aware of any attempt to validate users' reports of the absence of treatment in a household survey, and in the absence of such data, we acknowledge that this could be a substantial source of bias. However, in NetMark surveys, net owners' responses about net treatment have been compared with their responses about other net characteristics including brand, bundling, and source of the net, and have been found to be generally consistent. The NetMark 2000 data from several countries show that most public sector nets (70% or more) were reported as treated, whereas most commercial nets (80% or more) were not (C Baume and C Marin, NetMark, Washington DC, USA, personal communication).

When ITNs are delivered in the form of a net packaged with a sachet of insecticide, as in many social marketing projects, the recipient may choose not to use the insecticide to treat their net. In this case there is no misclassification of the treatment status of the net, but the logic of our assumption would result in a project net being misclassified as delivered through the commercial sector. Studies done by social marketing projects in Malawi and Tanzania found that most nets sold bundled with insecticide were treated with the insecticide, 88% within 8 months in Malawi, and 92% within 12 months in Tanzania (D Chavasse [Population Services International, Kenya] and J Miller [Population Services International, Tanzania], personal communication). This data supports only low levels of misclassification within our model.

We used exactly the same data and questions in determining treatment status of nets that are currently used for the global monitoring of ever-treated net coverage, and therefore the misclassification biases in our study are no better or worse than those upon which global indicators are based. Such misclassification would only introduce a selection bias to our equity analysis if the misclassification varies among socioeconomic groups. There is no evidence at present to allow the potential for this type of bias to be investigated.

We know that in a few places, net-treatment programmes have converted some commercially supplied nets into ITNs. This practice would introduce a misclassification bias with nets supplied through commercial markets being misclassified as coming from projects. In some of the smaller countries—eg, The Gambia and Guinea Bissau—net treatment programmes almost certainly account for a substantial proportion of the observed ITNs. As far as we know, however, net-treatment programmes have been carried out only on a limited scale in most of the other surveyed countries. The effect of such a campaign on our analysis would be to cause the coverage achieved by commercial markets to be underestimated.

Although acknowledging the possible biases, we do not believe that bias of this kind can reconcile the observed results, in particular the seven to one ratio between never-treated and ever-treated net coverage, with the common supposition that most nets in Africa have come from public-health programmes and projects. Similarly, we do not believe that bias of this kind can explain why observed ever-treated net coverage is so much more inequitable than never-treated net coverage.

Our analysis shows that demographic and health surveys, multiple-indicator cluster surveys and other nationally representative surveys can be a powerful tool for comparing the performance of different intervention delivery systems. They can show which delivery channels are reaching which kinds of people, including the poor. Such surveys are currently designed and used mainly as a tool for monitoring progress towards international targets, as recently presented in the *Africa malaria report*.[6] This monitoring is a key task at the global level, but for national control programme managers, information about the relative performance of local delivery systems is more useful. In this case, we used the reported treatment history of a net to identify its probable source. This interpretation will no longer be possible in many countries in the next round of household surveys, partly because insecticide-treatment kits are becoming more widely available (through both commercial and project activities), and because of growing public-health interest in implementing (re)treatment campaigns. Nevertheless, we have shown in recent work in Ghana that it is not difficult to identify the source of a net by, for example, the interviewer matching a net to a series of fabric swatches corresponding to various types of nets available locally (JW and M Kweku [Gates Malaria Programme, London School of Hygiene and Tropical Medicine, London, UK, and Ho District Health Authority, Ghana], unpublished data).

Public and private delivery systems, operating in parallel, also have an important role in the delivery of several other essential interventions. Antimalarial drugs are one important example. The development of methods to identify the delivery systems by which such interventions reach their targets should now be a priority. This is important for resolving international debates about alternative strategies. It is also important for national-level planners, who often have to try to ensure complementarity and coordination between competing alternative delivery systems. Without this kind of information it is difficult to make the best use of limited public sector resources. For example, our analysis suggests that national (re)treatment campaigns may be an appropriate next step for quickly scaling-up the equitable coverage of ITNs in several countries of west, central, and Sahelian countries of Africa, as well as in Madagascar. Recent small-scale experience in Cameroon suggests that such campaigns provide a strong incentive for net purchase, and can produce a substantial and very rapid increase in net coverage.[21]

The public-health importance of the UTNs currently delivered through commercial channels depends upon the degree to which they protect against malaria. The data on this question are less extensive than those on ITNs, but are nevertheless remarkably consistent,[22–29] and suggest that use of a UTN gives about half as much protection against malaria morbidity and mortality as use of an ITN. There is evidence that UTNs might divert mosquitoes to nearby people without nets,[30] which could be a problem if, within net-owning households, priority for net use were given to adults (especially adult men) rather than to children. However, in practice it seems that this is not a problem. Surveys conducted by the NetMark project, for example, have shown that in net-owning households in Nigeria,[31] Senegal,[32] Mali,[20] Zambia,[33] Uganda,[34] and Mozambique,[35] children under the age of 5 years were more likely than any other age group to be sleeping under a net, while the lowest net-usage levels were seen in adult men and older children (5–14 years), suggesting that children under the age of 5 years are more likely to benefit than to suffer from any diversion effect. Further, there is evidence from The Gambia and Papua New Guinea that a high level of community coverage with good quality UTNs can be positively beneficial to children without nets (or using a net with many holes) in the same community.[22,27,29] Assuming that UTNs are indeed approximately half as protective as ITNs, these figures imply that untreated (mainly commercial) nets are currently preventing a much larger number of child malaria deaths in Africa than are the relatively small number of ITNs delivered by projects. Moreover, this is the case not only in the general population, but also and especially in the most vulnerable target groups—children under the age of 5 years in the poorest households.

We conclude that the public-health importance of unsubsidised commercial markets in UTNs has been underestimated. The observation that most nets used by children under the age of 5 years are untreated is consistent with previous reports on overall national coverage,[6,36] but the implications of this finding for the evaluation of different net delivery systems has not so far been recognised. Our analysis is based on the assumption that observed patterns of ever-treated net coverage broadly reflect the direct and indirect results of the activities of public-health projects and programmes, while observed patterns of never-treated net coverage broadly reflect the activities of unsubsidised commercial markets. If correct, our data represent a major challenge to the supposition that most nets owned by poor people in Africa come from public-health programmes and projects. In fact they suggest that commercial supplies and delivery systems are a more important source, having achieved far greater overall coverage than ITN projects (including social marketing projects), and having been far better at reaching the poor. Policymakers at the national and international levels should consider these findings as they decide how best to design systems for delivering this critical public-health intervention in an equitable and efficient manner.

Search and selection criteria

We searched for nationally representative surveys in sub-Saharan African countries containing data on immunisation and the use of nets by children under 5 years of age, together with the treatment status of those nets, and the socio-economic status of the households. The analysis includes the most recent surveys publicly available in Sept 2004, excluding those done before 1999.

Conflicts of interest

We declare that we have no conflicts of interest.

Acknowledgments

Fred Arnold (ORC Macro) and Carol Baume (NetMark Project) reviewed earlier drafts of the manuscript and provided useful comments for improving the manuscript. JW, JL, and JB are funded by the Department for International Development (DFID) through the Malaria Knowledge Programme at the London School of Hygiene and Tropical Medicine. JRMAS is funded by the Bill and Melinda Gates Foundation through the Gates Malaria Partnership. KH is funded by DFID through the Health Economics and Financing Programme at the London School of Hygiene and Tropical Medicine. The views represented in this article are those of the individual authors and do not represent the views of their institutions.

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