

## Assessment of Insecticide-Treated Bednet Use Among Children and Pregnant Women Across 15 Countries Using Standardized National Surveys

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**Abstract.** Impact of insecticide-treated bednets (ITNs) on preventing malaria may be minimized if they are not used by vulnerable populations. Among ITN-owning households from 15 standardized national surveys from 2003 to 2006, we identify factors associated with ITN use among children younger than 5 years of age and make comparisons of ITN use among children and pregnant women across countries. Within ITN-owning households, many children and pregnant women are still not using them. Between-country analysis with linear regression showed child ITN use increases as intra-household access to ITNs increases ( $P = 0.020$ ,  $R^2 = 0.404$ ), after controlling for season and survey year. Results from within-country logistic regression analyses were consistent with between-country analysis showing intra-household access to ITNs is the strongest and most consistent determinant of use among children. The gaps in ITN use and possession will likely persist in the absence of achieving a ratio of no more than two people per ITN.

### INTRODUCTION

Insecticide-treated bednets (ITNs) have been shown to significantly reduce malaria-related morbidity and all-cause child mortality across a range of transmission settings in Africa.<sup>1</sup> With increased funding from international donors, efforts are currently underway to roll-out ITNs to vulnerable populations at risk of malaria across sub-Saharan Africa (SSA), particularly children younger than 5 years old and pregnant women. The Roll Back Malaria Partnership (RBM) has recently set the target of protecting 80% of children and pregnant women at risk for malaria with ITNs by 2015.<sup>2</sup> However, the impact on preventing malaria morbidity and malaria-related mortality may be minimized if ITNs are not properly and consistently used by vulnerable populations.

Although ITNs are increasingly accessible in many SSA countries, getting people to correctly and consistently use ITNs has proven difficult.<sup>3–8</sup> A previous multi-country assessment in SSA using national and sub-national household surveys between 1991 and 2001 found a considerable gap between use and possession among children.<sup>6</sup> The analysis showed that household possession of ITNs ranged from 0.1% to 29%, whereas use by children younger than 5 years old ranged from 0% to 16%. Within households possessing at least one ITN, only 55% of children were found to have slept under an ITN the previous night. In another study using data from sub-national NetMark surveys conducted between 2000 and 2004, the researchers showed that bednet use among children younger than 5, within households with at least one bednet, ranged from 48% to 73%, while use among pregnant women ranged from 18% to 69%.<sup>9</sup>

This analysis improves on these previous analyses in several important ways. First, since these two multi-country analyses were conducted, there has been considerable effort to scale-up ITN coverage and standardize data collection protocols, instruments, and indicators for measuring household ITN possession and use at the national level.<sup>10,11</sup> Second, with increased demand for data to evaluate the impact of national ITN scale-up efforts, there has been an increased effort to collect standardized national level population-based data on ITN household possession and use across many countries in Africa

every 3–5 years, providing an excellent opportunity to update previous estimates of core coverage indicators. Last, unlike sub-national surveys with varying sampling methods and stratification schemes, the surveys used in this analysis are standardized, population-based, and representative at the national level, allowing their results to be compared between countries and over time.

This paper presents data on ITN household possession and use among children and pregnant women from 15 standardized national surveys conducted between 2003 and 2007. Within each country, we present factors associated with ITN use among children younger than 5 within ITN-owning households to isolate factors other than access to an ITN influencing use. We also present a comparison of ITN use among children and pregnant women across countries with varying levels of ITN ownership, restricted to ITN-owning households. Although we recognize that information on the use of bednets, treated or untreated, is useful for investigating factors related to their use, this analysis focused on ITNs only because 1) ITNs are consistent with international targets; 2) ITNs, especially long-lasting ITNs, are increasingly more prevalent in SSA than untreated nets; and 3) ITNs have a larger impact on preventing malaria and thus their use is likely different from older untreated nets.

### MATERIALS AND METHODS

**Data sources.** Nationally representative, population-based data from the Demographic and Health Survey (DHS), the Multiple Indicator Cluster Survey (MICS), and the Malaria Indicator Survey (MIS) were used to investigate ITN use among children and pregnant women. Criteria for inclusion were survey data collected between 2003 and 2007; data made publically available by April 1, 2008; country located in sub-Saharan Africa (SSA); at least 150 households in the survey data possessing an ITN; and sufficient information in the data for determining whether a net is treated or untreated at the household level according to the RBM definition.<sup>11</sup> Data sets from 15 SSA countries met these inclusion criteria and were obtained from MEASURE DHS (DHS and MIS) and UNICEF (MICS).

The DHS, MICS, and MIS all use similar probability sampling techniques consisting of a two-stage cluster sample, probability proportional to estimated cluster size, to obtain

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a sample of households and individuals that are comparable between countries. The DHS and MIS use standardized household questionnaires with a net roster linked to a list of all household occupants who slept under each net the previous night to ascertain household ITN possession and use. The MICS typically obtains such data for household ITN possession and use among children from a standardized woman's questionnaire and not a net roster.

**Data analysis.** All analyses were done using STATA 9.0 (STATA Corp., College Station, TX). Survey data from the 15 countries were used to estimate ITN household possession and use among children younger than 5 years of age and pregnant women. Nets were reclassified as ITNs or untreated nets according to the RBM definition as a bednet that has been treated with insecticide within the past 12 months or is a long-lasting ITN.<sup>11</sup> Information on the brand of net, time of acquisition, and time since last re-treatment were obtained from households using standardized questions and a net roster linking household residents to each net (note: MICS only links children to ITNs, not all household residents).

For comparisons across countries with varying levels of ITN household possession, we calculated standardized indicators for the proportion of children younger than 5 years old and pregnant women who slept under an ITN the previous night, within households possessing at least one ITN. This was done to isolate factors other than household access to an ITN that influence use. The following indicators for children were calculated among ITN-owning households: the proportion of children younger than 5 years old that slept under an ITN the previous night and the proportion of households with all children younger than 5 covered by an ITN the previous night. For pregnant women within ITN-owning households, we calculated the proportion of pregnant women that slept under an ITN the previous night. For assessing intra-household access to ITNs among children and pregnant women in ITN-owning households, we calculated the ratio of household members to ITNs owned by the household. The MICS questionnaire only collect information on one net per household; thus, there was insufficient information in these surveys to calculate the ratio

of household members per ITN. The MICS also does not collect data on whether a pregnant woman slept under an ITN the previous night.

For each country separately, a logistic regression model was used to examine within-country factors that might influence ITN use by children. This analysis was limited to children within ITN-owning households to eliminate the influence of household ITN access. Based on previous research,<sup>6,7,9,12-14</sup> factors measured in the DHS, MICS, and MIS hypothesized to be associated with ITN use included child's age, the mother's education, the ratio of household members per ITN(s), child's sex, place of residence (urban/rural), household socioeconomic status, and mother's ethnicity (note: mothers' ethnicity was not available for Rwanda, Tanzania, Uganda, Zimbabwe, and Sierra Leone; in the case of Cote d'Ivoire, ethnicity of head of household was used as a substitute). Because there were insufficient data to ascribe a transmission season to each survey date at the household level within each country, transmission season within each country was assumed to be constant for all within-country analyses. The child age variable was dichotomized as < 1 year old and  $\geq 1$  but < 5 years old, based on previous research that showed infants more likely to use a bednet than older children.<sup>9,15</sup> The variable for mother's education was categorized as no education, some primary education, and primary or higher education. The ratio of household residents per ITN was dichotomized using the median cut point into high versus low within each country (Table 1). A household asset index was used as a proxy indicator for household socioeconomic status within each country. The index was developed based on a principal components analysis of household assets, dwelling materials, sanitation facilities, and sources of drinking water, with raw factor scores divided into quintiles.<sup>16</sup> No such analysis was undertaken among pregnant women because of limitations in sample size and resultant statistical power.

To explore how intra-household access to ITNs affects use by children, a between-country analysis was undertaken using linear regression to quantify the relationship between the mean ratio of household residents per ITN (as a proxy

TABLE 1

Summary statistics presenting ITN coverage and use estimates for children younger than 5 years old within 15 national level surveys in sub-Saharan Africa 2003–2006

	Among households with children < 5 years old and $\geq 1$ ITN, mean ratio of household residents per ITN			Among households with $\geq 1$ ITN, proportion with all children < 5 years old covered by an ITN the previous night		Among households with $\geq 1$ ITN, proportion of children that slept under an ITN the previous night		Among households with children < 5 years old and $\geq 1$ ITN but no child used an ITN the previous night, proportion of households where $\geq 1$ adult $\geq 15$ years old slept under an ITN the previous night	
	N	Median	Mean (SE)	N	% (SE)	N	% (SE)	N	% (SE)
Benin (DHS 2006)	2,918	4.0	4.40 (0.06)	2,918	65.45 (1.09)	4,782	67.98 (1.05)	655	53.09 (2.16)
Burkina Faso (DHS 2003)	294	4.0	5.57 (0.25)	294	40.40 (3.57)	449	41.33 (3.52)	132	69.49 (5.17)
Cameroon (DHS 2004)	337	5.0	5.57 (0.22)	337	41.40 (3.19)	571	43.74 (3.05)	141	40.14 (5.41)
Congo (DHS 2005)	259	4.0	4.37 (0.22)	259	65.59 (4.19)	366	70.51 (3.64)	61	55.01 (7.07)
Cote d'Ivoire (MICS 2006)*	—	—	—	567	33.58 (3.73)	567	41.26 (3.76)	—	—
Ethiopia (DHS 2005)	415	5.0	5.47 (0.21)	415	32.62 (4.16)	584	39.05 (3.95)	234	23.61 (4.64)
Ghana (DHS 2003)	231	5.0	5.26 (0.22)	231	47.64 (3.76)	367	50.16 (3.37)	81	42.50 (5.90)
Kenya (DHS 2003)	368	3.0	3.84 (0.17)	368	69.38 (2.87)	529	71.21 (2.82)	58	57.55 (7.24)
Malawi (DHS 2004)	2,529	3.5	3.93 (0.051)	2,529	44.00 (1.35)	3,618	45.76 (1.40)	1,222	17.80 (1.53)
Rwanda (DHS 2005)	1,123	4.0	4.72 (0.07)	1,123	57.23 (1.65)	1,763	63.45 (1.48)	283	42.57 (3.15)
Senegal (MIS 2006)	908	5.0	6.79 (0.27)	908	29.77 (2.44)	2,178	36.14 (2.62)	424	35.29 (3.30)
Sierra Leone (MICS 2005)*	—	—	—	314	41.37 (3.97)	314	46.98 (3.88)	—	—
Tanzania (DHS 2004)	1,205	3.0	3.70 (0.11)	1,205	65.94 (1.83)	1,791	67.72 (2.25)	330	44.97 (3.48)
Uganda (DHS 2006)	1,053	4.0	4.88 (0.10)	1,053	47.67 (1.62)	1,698	53.72 (1.45)	379	51.81 (2.78)
Zimbabwe (DHS 2006)	490	4.0	4.63 (0.11)	490	27.28 (2.67)	658	27.63 (2.28)	337	21.30 (2.58)

\* The ratio of household residents per ITN could not be calculated because the MICS does not collect data on the number of ITNs within the household.

for intra-household access) and the outcome of the proportion of children using ITNs in each country. This analysis was limited to children within ITN-owning households to eliminate the influence of household ITN access. The model controlled for seasonality by creating a dummy variable to indicate overlap between the survey data collection period (mean of 4.9 months across the 15 surveys) and initial month of malaria transmission season (typically two transmission seasons per year), which is assumed to be close to peak densities in biting mosquitoes. The first month of a transmission season in each country was obtained from the latest (2001) transmission map from the Mapping Malaria Risk in Africa project (MARA).<sup>17</sup> The data collection fieldwork in 8 of the 15 countries included here (Burkina Faso, Cameroon, Ethiopia, Kenya, Malawi, Tanzania, Uganda, and Zimbabwe) overlapped with the first month of a malaria transmission season, which typically follows the rainy season by several weeks. The model also controlled for survey year to account for potential fluctuations in regional malaria transmission and ITN scale-up efforts.

Generalized estimating equations (GEEs) were used to obtain empirically estimated standard errors in logistic regression models for within-country analyses, using the primary sampling unit as the cluster unit. All point estimates were weighted to account for discrepancies in estimated versus actual cluster sizes at first stage selection (*pweight*) for all analyses. The probability of committing a type 1 error ( $\alpha$ ) was set at 0.05.

## RESULTS

The proportion of households, with a child younger than 5 years of age, possessing at least one ITN ranged from 3.9% to 42.0%, whereas the proportion of children who slept under an ITN the previous night ranged from 1.5% to 20.0%, among all households with or without an ITN (Figure 1). The proportion of households, with a pregnant woman, possessing at least one ITN ranged from 3.3% to 44.2%, whereas the proportion of pregnant women who slept under an ITN the previous night ranged from 1.1% to 19.7% among all households with or without an ITN (Figure 2).

Among ITN-owning households with a child younger than 5, the mean ratio of household residents to ITNs ranged from

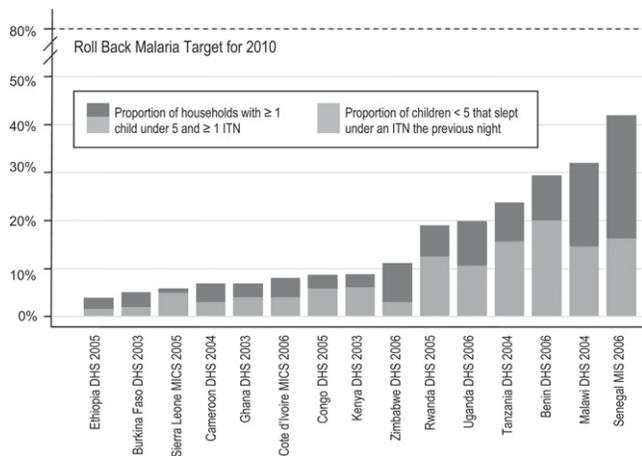


FIGURE 1. Summary description of ITN household possession and ITN use among children younger than 5 years old across 15 national level surveys in sub-Saharan Africa 2003–2006.

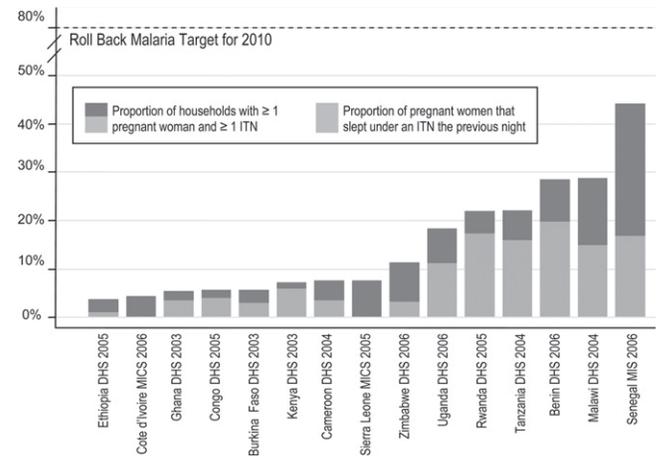


FIGURE 2. Summary description of ITN household possession and ITN use among pregnant women across 15 national level surveys in sub-Saharan Africa 2003–2006.

6.8 people per ITN in Senegal (2006) to 3.7 in Tanzania (2004) (Table 1). The proportion of children that slept under an ITN the previous night within ITN-owning households ranged from 27.6% in Zimbabwe (2003) to 71.2% in Kenya (2006). The proportion of such households with all children using an ITN ranged from a low of 27.3% to a high of 69.4% within these same countries, respectively. Within ITN-owning households where no children younger than 5 used an ITN the preceding night, use of an ITN among at least one adult (at least 15 years old) in the house ranged from 17.8% to 69.5%. The proportion of pregnant women using an ITN, within ITN-owning households, ranged from 29.1% to 82.3%, within Zimbabwe and Kenya, respectively (Table 2). The proportion of ITN-owning households with no one sleeping under one ranged from 8.7% to 52.2%.

Results from the within-country logistic regression analyses, among ITN-owning households, showed that intra-household access to ITNs (the ratio of household members per ITN) was the strongest and most consistent household factor associated with ITN use among children, while controlling for child's age, mother's education, socioeconomic status, sex of child, urban/rural residence, and ethnicity (Table 3). Across the 15 national surveys analyzed here, children in ITN-owning households with better intra-household access to an ITN (lower ratio of household members per ITN) were between 2.1 and 5.5 times more likely to have slept under an ITN the night before the survey, except in Ethiopia, where this ratio was not significantly associated with child ITN use. Additionally, in 7 of the 15 countries analyzed, the odds that a child slept under an ITN the night before the survey increased significantly among infants compared with older children 1–5 years old, while controlling for the covariates noted above. Mother's education was not a consistent predictor of ITN use among children in net-owning households, after controlling for intra-household access to ITNs, socioeconomic status, and the other potential confounders noted above. Socioeconomic status, sex of child, urban/rural residence, and ethnicity were not significantly associated with ITN use among children in ITN-owning households in any of the 15 countries.

The between-country analysis using linear regression showed that, among ITN-owning households, an inverse relationship

TABLE 2

Summary statistics presenting ITN coverage and use estimates for pregnant women within 15 national level surveys in sub-Saharan Africa 2003–2006

	Among households with pregnant women and $\geq 1$ ITN, mean ratio of household residents per ITN		Among pregnant women living in households with $\geq 1$ ITN, proportion that slept under an ITN the previous night	
	N	Mean (SE)	N	% (SE)
Benin (DHS 2006)	534	4.25 (0.14)	552	69.43 (2.05)
Burkina Faso (DHS 2003)	63	5.71 (1.06)	66	53.15 (6.24)
Cameroon (DHS 2004)	70	4.82 (0.60)	74	44.59 (7.25)
Congo (DHS 2005)	33	4.17 (0.58)	34	73.13 (8.62)
Cote d'Ivoire (MICS 2006)*	—	—	—	—
Ethiopia (DHS 2005)	54	5.35 (0.48)	55	32.13 (8.19)
Ghana (DHS 2003)	29	4.66 (0.53)	30	67.72 (11.48)
Kenya (DHS 2003)	52	2.95 (0.20)	52	82.27 (6.26)
Malawi (DHS 2004)	440	3.49 (0.10)	435	52.32 (2.81)
Rwanda (DHS 2005)	216	4.14 (0.15)	210	79.99 (2.96)
Senegal (MIS 2006)	211	7.45 (0.52)	233	38.24 (3.85)
Sierra Leone (MICS 2005)*	—	—	—	—
Tanzania (DHS 2004)	221	3.64 (0.19)	224	72.88 (3.46)
Uganda (DHS 2006)	175	4.74 (0.21)	180	60.44 (4.18)
Zimbabwe (DHS 2006)	67	4.27 (0.34)	68	29.10 (6.06)

\* The MICS does not collect data to calculate the ratio of household residents per ITN or the proportion of pregnant women who slept under an ITN the previous night.

existed between the proportion of children younger than 5 using an ITN and the mean intra-household ratio of residents per ITN ( $F_{1,11} = 7.44$ ,  $P = 0.020$ ), after controlling for season and survey year (Figure 3). Forty percent ( $R^2 = 0.404$ ) of the variation in the proportion of children sleeping under an ITN across 13 countries can be explained by the ratio of household residents per ITN. There was a 13% decrease in the proportion of children using ITNs for each additional household resident per ITN [ $\hat{Y} = \beta_0(125.48) - \beta_1(12.59) \times \text{Resident to ITN ratio} + E$ ].

## DISCUSSION

We analyzed recent data from 15 standardized national surveys conducted in SSA between 2003 and 2006 to assess ITN use among children and pregnant women. We also explored factors associated with ITN use among children in ITN-owning households. Results showed that access to ITNs is still a major limitation within most of the countries

analyzed; only three countries were found to have achieved > 25% coverage of ITN household possession among households with a child younger than 5 years of age. Results also suggested that, within ITN-owning households, many children and pregnant women are still not sleeping under them; within the majority (9/15) of countries analyzed, less than one half the children in such households were using them, while in 4 of 14 countries, less than one half the pregnant women were using them.

However, results also showed that, within ITN-owning households, several countries—Benin, Congo, Kenya, Rwanda, and Tanzania—achieved ITN use among children, ranging from 63.5% to 71.2%, which is approaching levels of child net use observed under ITN trial conditions.<sup>18,19</sup> Moreover, within these same countries, the proportion of ITN-owning households with all children younger than 5 using an ITN was similarly high, ranging from 65.5% to 69.4%. ITN use among pregnant women was even more pronounced within ITN-owning households, with more than one half the countries

TABLE 3

Adjusted odds ratios predicting ITN use by child younger than 5 years old among households with  $\geq 1$  ITN, within 15 national level surveys in sub-Saharan Africa 2003–2006

	N	Ratio of household residents per ITN		Age of child		Mother's education	
		Median and below Reference: above median value		Infant (< 1 year) Reference: child between at least 1 to under 5 years		Some primary Reference: no education	
		AOR (95% CI)		AOR (95% CI)		AOR (95% CI)	
Benin (DHS 2006)	4,475	4.69 (3.93–5.60)*	1.58 (1.33–1.87)*	0.98 (0.79–1.22)	1.14 (0.89–1.45)		
Burkina Faso (DHS 2003)	399	5.15 (2.80–9.47)*	1.52 (0.80–2.86)	4.06 (1.56–10.57)†	0.70 (0.32–1.55)		
Cameroon (DHS 2004)	480	3.51 (2.28–5.39)*	2.22 (1.37–3.62)†	1.87 (0.63–5.50)	2.92 (1.08–7.90)‡		
Congo (DHS 2005)	313	5.53 (2.50–12.22)*	1.19 (0.49–2.91)	0.55 (0.12–2.57)	0.88 (0.22–3.49)		
Cote d'Ivoire (MICS 2006)	463	—	2.23 (1.22–4.08)†	2.01 (1.16–3.64)‡	1.14 (0.50–2.59)		
Ethiopia (DHS 2005)	529	1.36 (0.73–2.54)	0.96 (0.48–1.95)	1.34 (0.60–3.00)	1.86 (0.75–4.60)		
Ghana (DHS 2003)	322	2.30 (1.30–4.09)†	1.92 (1.05–3.52)‡	0.92 (0.38–2.23)	1.24 (0.59–2.57)		
Kenya (DHS 2003)	481	4.86 (2.70–8.76)*	1.47 (0.83–2.61)	0.58 (0.14–2.46)	0.34 (0.08–1.46)		
Malawi (DHS 2004)	3,232	2.09 (1.71–2.56)*	1.27 (1.07–1.51)†	1.55 (1.18–2.04)†	1.57 (1.13–2.18)†		
Rwanda (DHS 2005)	1,694	4.54 (3.38–6.09)*	2.10 (1.57–2.80)*	1.09 (0.70–1.70)	0.97 (0.60–1.58)		
Senegal (MIS 2006)	1,911	4.76 (3.56–6.36)*	1.24 (0.97–1.60)	0.74 (0.47–1.14)	1.00 (0.57–1.76)		
Sierra Leone (MICS 2005)§	314	—	1.19 (0.67–2.11)	0.87 (0.36–2.10)	1.14 (0.46–2.81)		
Tanzania (DHS 2004)	1,654	2.36 (1.72–3.22)*	1.10 (0.83–1.46)	1.04 (0.57–1.87)	1.66 (1.05–2.65)‡		
Uganda (DHS 2006)	1,536	2.78 (2.12–3.65)*	1.50 (1.15–1.97)†	1.23 (0.87–1.75)	1.46 (0.95–2.24)		
Zimbabwe (DHS 2006)	589	3.07 (1.84–5.13)*	1.13 (0.70–1.82)	2.27 (0.54–0.54)	2.30 (0.55–9.67)		

Full logistic regression model also included child's sex, place of residence (urban/rural), household socioeconomic status (quintiles using asset index), and ethnicity.

Significant: \*  $P < 0.0001$ ; †  $P < 0.01$ ; ‡  $P < 0.05$ .

§ The ratio of household residents per ITN could not be calculated as the MICS does not collect data on the number of ITNs within the household.

AOR = adjusted odds ratio; CI = confidence interval.

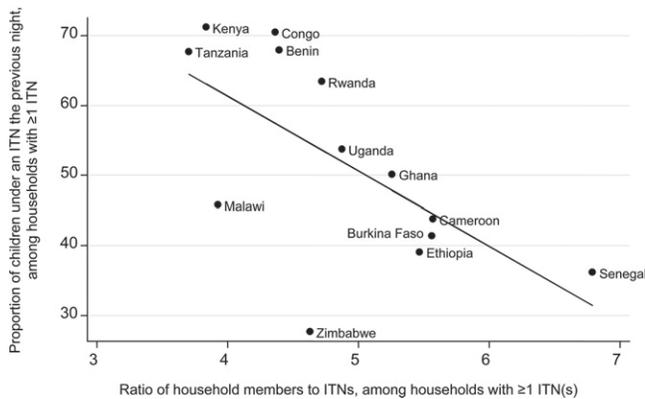


FIGURE 3. Relationship between child ITN use and the ratio of household members to ITNs, among households with at least one ITN, across 14 national level surveys in sub-Saharan Africa 2003–2007. Regression model controlled for season of data collection and year of survey fieldwork in each country ( $F_{1,11} = 7.44$ ,  $P = 0.020$ ,  $R^2 = 0.404$ ).

analyzed (8/14) showing ITN use among pregnant women > 60%.

Results from both between- and within-country analyses for the 15 national surveys showed that ITN use by children increases as the intra-household availability of ITNs increases within ITN-owning households. This is supported by the fact that adults were reported to have used an ITN in the majority (11/13 countries analyzed) of ITN-owning households with children, where none of the children were protected. Such results are consistent with those reported elsewhere,<sup>6,7,9</sup> suggesting countries should aim to achieve greater than one ITN per household to ensure adequate intra-household access for children and pregnant women.

Results from the within-country analyses showed that infants are more likely to sleep under ITNs than older children, coinciding with previous observations.<sup>9,15</sup> This suggests that women and their infants, especially those that are still breast feeding, are using their ITNs together, suggesting ITN promotion to pregnant women through antenatal clinics is working.<sup>15</sup> However, these same results also suggest that, as children grow older, they may lose their access to ITNs to younger siblings, again suggesting that increasing intra-household ITN access is critical.

Although higher mother's education was associated with increased ITN use among children for several of the country-specific analyses, socioeconomic status was not a significant household-level factor associated with ITN use among children in ITN-owning households. Thus, although household socioeconomic status has been shown to influence household ITN possession in certain settings,<sup>20</sup> these results suggested that, once a household has an ITN, household wealth is not associated with ITN use among children. Therefore, these data show socioeconomic status influences ITN use through access to ITNs. After adjusting for intra-household access to ITNs, urban/rural residence, sex, and mother's ethnicity were also not significantly associated with ITN use among children in ITN-owning households in any of the within-country analyses, again supporting the premise that the primary factor influencing use among children is the number of nets in the house relative to the number of people sleeping in the house.

We would like to note several limitations in our analysis. First, the data analyzed here do not include several MIS

surveys conducted in 2006, namely the 2006 Zambia MIS, and none beyond this time point, because those data are not yet available. It is recognized that countries are rapidly scaling-up ITN distribution programs and thus many of the estimates of household ITN possession and ITN use among children and pregnant women may already be outdated. However, analyzing ITN use among vulnerable populations within ITN-owning households allows the comparison of intra-household net use patterns with future estimates as the data are made available, regardless of changes in coverage of household ITN possession. Second, contrary to previous findings,<sup>3,6,12,21</sup> seasonality was not found to be significantly associated with ITN use among children in the between-country analysis, after controlling for the mean ratio of household members per ITN and study year for each country in the model. It is likely season was not found to be significantly associated with ITN use in this analysis, because rainfall patterns within countries are heterogeneous, and malaria transmission highly localized; thus, their effect is not well captured from these data at the national level. Additionally, it is recognized that, for the within-country analyses of factors associated with ITN use where transmission season was assumed constant, the survey data collection period within each country may have actually overlapped differentially across high and low transmission seasons. However, there were insufficient data to ascribe transmission season at the household level within each country and thus the effect of season on ITN use within countries could not be assessed. Third, it is recognized that distinguishing between an ITN and an untreated bednet according to the RBM definition is subject to information bias on when nets were procured and retreated, resulting in non-differential date heaping at 1 year.<sup>22</sup> Last, it is acknowledged that ITN use among children and pregnant women ascertained from standard face-to-face household questionnaires may suffer from information bias when the respondents feel socially obligated to respond positively to questions about recent net use for themselves and their children, resulting in an overestimation of their use.<sup>23</sup>

It is likely that gaps between ITN use and possession may persist even if high coverage of at least one ITN per household is attained unless ITN distribution programs focus on achieving an appropriate household member to ITN ratio in line with two people per ITN.<sup>7,9,10,24</sup> Once intra-household access to ITNs is attained, the remaining gap between ITN use among children and pregnant women within households possessing them may be minimized further with behavior change communication campaigns (BCC). Evidence suggests that interpersonal communication through community outreach focusing on hanging nets and communicating the importance of using them is perhaps the most promising intervention to increase ITN use among ITN-owning households.<sup>25,26</sup>

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