Scale-up of Malaria Control Interventions and Reduction in All-Cause Mortality in Children Less than 5 Years of Age in Ghana 2003 – 2016

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Contents

Introduction

There were an estimated 219 million cases and 435,000 deaths from malaria worldwide according to the 2018 World Malaria Report. Nearly all (93%) of the deaths were in sub-Saharan Africa.[1] Since 2003, global investments in malaria control and elimination have increased nearly 20-fold, reaching US $2.9 billion in 2015.[2] These investments have been made with the expectation that they will cause substantial reduction in deaths due to malaria, particularly among children aged less than five years. [3-5]

Children aged 0-59 months are particularly vulnerable to malaria.[6] The major interventions deployed to reduce under-five deaths from malaria include the use of insecticide-treated nets (ITNs), intermittent preventive treatment of malaria in pregnant women (IPTp), prompt diagnosis and treatment of uncomplicated malaria using artemisinin-based combination treatments (ACTs), indoor residual spraying (IRS) and, where favourable climatic conditions exist, seasonal malaria chemoprevention (SMC). In many areas in malaria-endemic sub-Saharan Africa, the period of scale-up of malaria control interventions has coincided with substantial decline in under-five mortality rates.[7-9]

Methods

Study site

Ghana occupies a land area of 238,537 sq. km in West Africa. It has an estimated population of 29 million people, approximately 16% of whom are below five years of age.10 Malaria is endemic in all ten regions of Ghana and the entire population is at risk of the disease. There are three distinct zones of malaria transmission. These are the intense and seasonal transmission form in the three northern regions, a moderate and perennial form in the middle forest belt, and a lower but perennial form in the coastal south.[10,11] Entomological inoculation rates range from 418 infective bites per person per year in the northern regions to 231 in the middle-forest belt to five in the southern coastal lowlands regions.[12-14] The three northern regions of the country are generally regarded as the most under-served and tend to be targeted in the roll-out of health and other interventions.[15-17]

Figure 1. Map of Ghana

In 2016, Ghana recorded approximately 10.4 million suspected malaria cases through the routine district health information management system (DHIMS2), which represented about 39% of outpatient department (OPD) visits, 25% of total admissions and 4% of total deaths. Children under five years old and pregnant women were the most affected.[18]

The highest incidence of malaria in Ghana occurs during the rainy season (months). *Plasmodium falciparum* is responsible for more than 95% of malaria cases. The dominant vector species are *Anopheles gambiae*, *Anopheles funestus* and *Anopheles arabiensis*.[19,20] The major interventions to control malaria in Ghana are ITNs, IPTp with sulfadoxine-pyrimethamine (SP), prompt diagnosis and treatment of uncomplicated malaria using ACTs, IRS and SMC.[18,21,22]

While the implementation of ITNs, ACTs and IPTp has been nationwide, the deployment of IRS and SMC have largely focused on the three northern regions. SMC, which involves administration of full treatment doses (4 rounds) of SP and amodiaquine (AQ) to children under 5 years old at monthly intervals from mid-June to mid-September,[17] was introduced in 2015 in the Upper West Region and extended in 2016 to the Upper East in northern Ghana. In-door residual spraying (IRS) is implemented before the rainy season to provide protection once the malaria transmission season begins. IRS was initially implemented in one district in the Ashanti Region in 2006. Although it has been extended to other regions, mostly in the north, < 5% of the country's population was protected by IRS in 2016.

In 2005, the Government of Ghana, in collaboration with the Ministry of Health and the Ghana Health Service, adopted the Community-Based Health Planning and Services (CHPS) as a national policy for the provision of primary health care services. The National/District Health Insurance Scheme (N/DHIS) is an intervention in national health care financing that was introduced in 2003 to promote universal access to health care. From a reported coverage for women of 38.8% in 2008, coverage stood at 58.0% by 2016.

In early 2010, WHO issued revised treatment guidelines that call for a shift from the presumptive to the test-based approach. Based on research in Ghana and other countries, and evidence from program work, the Ghana National Malaria Control Programme issued revised national treatment guidelines that call for implementation of test-based management of malaria in all cases, and across all age groups.[22]

Major non-malarial interventions

Between 2003 and 2014, new vaccines were introduced into the routine immunization programs. These included the pentavalent vaccine which contains antigens for diphtheria, pertussis, tetanus, pneumococcus and rotavirus. Campaigns were launched to promote use of oral rehydration salts (ORS) and zinc the management of diarrhoea. Vitamin A supplementation was also initiated as well as intensified promotion of modern family planning methods and HIV testing and treatment. Health access also improved through the launch of community health posts and the national health insurance scheme.

Under-five mortality

Under-five mortality rates in Ghana declined 50% between 1993 and 2014, from 119 to 60 deaths per 1,000 live births.[23] The period of greatest decline was between 2003 and 2014. To date there has been no systematic exploration of the relationship between the scale-up of malaria control interventions and the reduction in under-five mortality. In 2017, the National Malaria Control Programme (NMCP), in partnership with USAID/Ghana's Evaluate for Health project, commissioned an evaluation of the impact of malaria control interventions on all-cause under-five mortality in Ghana during 2003 – 2016, when increases in intervention coverage occurred.[24,25] This paper is an output of the evaluation.

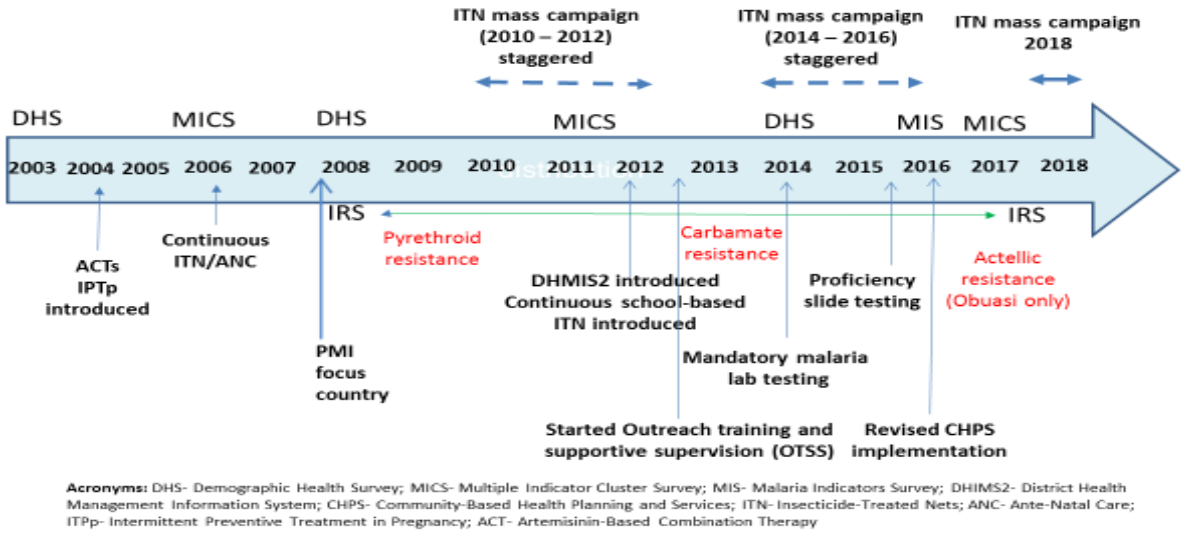
Evaluation Design

We used a plausibility design[26,27] to explore the possible contribution of interventions in malaria control to reduction in all-cause under-five mortality in Ghana between 2003 and 2016. All-cause under-five mortalities were extracted from national household surveys. Confidence intervals were constructed to gauge extent of changes in rates over time. The changes in outcome measure (ACCM) and malaria control intervention coverage were compared in terms of direction, temporality and significance to explore the case for plausible relationship.

The data used in the analysis were the Ghana Demographic and Health Survey (GDHS, 2003, 2008 and 2014), the Multiple Indicator Cluster Survey (MICS, 2006 and 2011) and the Malaria Indicator

Survey (MIS, 2016). All surveys were conducted by the Ghana Statistical Service and details of the various methodologies are captured in respective reports and publications.[23] The temporal relationship between the introduction of various malaria control interventions and the times when data was collected are shown in **Figure 2**.

Figure 2. Timeline of evaluation data sources and malaria control interventions



Acronyms: DHS- Demographic Health Survey; MICS- Multiple Indicator Cluster Survey; MIS- Malaria Indicators Survey; DHIMS2- District Health Management Information System; CHPS- Community-Based Health Planning and Services; ITN- Insecticide-Treated Nets; ANC- Ante-Natal Care; ITPp- Intermittent Preventive Treatment in Pregnancy; ACT- Artemisinin-Based Combination Therapy

Data Sources and Variables

Descriptive Analyses

Data sets from the full reports of the surveys were accessed and manipulated to calculate coverage of malaria control interventions. Data on under-five mortality were obtained from the surveys conducted in 2006 (MICS), 2008 (GDHS), 2011 (MICS), and 2014 (GDHS). Beyond the 2006-2014 studies, data from the 2016 MIS were used to illustrate additional data trends after the evaluation period.

Regression Analyses

We used the data from the 2003, 2008 and 2014 Ghana Demographic Health Surveys (DHS) in regression analysis that explored the relationship between possession and use of ITNs and under-five child survival. The dataset included full birth history of all women within the reproductive age (15-49 years). This birth history included all children born alive to women of reproductive age and

their survival status. The children's data files were merged with household data to obtain a complete dataset required for the analysis. The children's data contain information related to the child's antenatal and postnatal care and immunization and health, including the data for the mother of each of these children. In addition, the file contains child health indicators such as bednet use, immunization coverage, vitamin A supplementation, and recent occurrences of diarrhea, fever and cough for young children and treatment of childhood diseases. The household data contain information about the sex of the household head, age, place of residence, household wealth, sanitation, access to improved water source, etc. Information about the year of the child's birth, whether each child was alive at the time of the survey, and how old a child was if s/he died was used to define a binary outcome of death among each child less than 5 years old during the five years preceding the survey. The exposure variables of interest were household ownership of ITN, number of children in the household that slept under an ITN the previous night and whether the child's mother slept under an ITN the previous night. Number of months each household had owned the bed-net was also included.

Co-variates

We extracted additional variables that were associated with child survival in other reports and used them as covariates in the regression models. These variables were categorized into household characteristics (sex of the household head, age of the head, household size, place of residence, region, household wealth, household access to improved water and toilet facilities), maternal characteristics (mother's age first birth, current age of mother, marital status, highest educational level and body mass index), child characteristics (age of the child, sex of the child, multiple birth, birth order and preceding birth interval).

Individual level analysis

Poisson model: We performed an individual-level modified Poisson model with robust standard error to assess the association between children that slept under an ITN the previous night and mortality in children aged 0–59 months, using data from the 2003, 2008 and 2014 Ghana DHS. We assumed that the relationship between ITN use and ITN ownership is fairly linear and that non-use of ITN is largely determined by lack of access [28,29]. Indeed, households with ITN are likely to use it which explains why ITN use among households with ITN is generally high. Although it would have been preferable to use data on ITN use by individual children as the exposure variable during the survival period, DHS data on ITN use only referred to use in the night preceding the survey visit.

Cox-proportional hazard model: We fitted a Cox proportional hazard model to compare the hazard rate of mortality between the children/women who slept under an ITN the previous night and children/women that did not sleep under an ITN the previous night. We assumed that mothers/children that slept under-ITN the night before the survey may have developed the habit of sleeping under ITN long before the survey, and it was; therefore, a good proxy for ITN use before the survey. [30] We used life table procedure and Kaplan-Meier survival analysis to compare estimates of under-five mortality and cumulative incidence rates between children that used an ITN and those who did not.

To obtain an unbiased estimate from both regression models, we accounted for complex survey design structure (clustering, stratification and weighting). To estimate population-level mortality and assess the relationship between ITN use and mortality using data pooled from different surveys, we de-normalized women sampling weights. This was done by dividing the women standard weight by the women survey sampling fraction; that is, the ratio of total number of women aged 15-49 years interviewed in the survey year over the total number of women aged 15-49 years in the country at the time of the survey. The total number of women aged 15-49 interviewed in the survey year was obtained from the DHS datasets, while the total number of women aged 15-49 years in the country at the time of the survey was obtained from *OurWorldinData,* World Population Growth 2017,[31] which provides annual population estimates by country, disaggregated by sex.

Regional level (Ecological) analysis

The regional level analysis was conducted to assess the impact of coverage of ITN on all-cause under-five mortality in Ghana. Regional-based aggregate data on household ownership of bed net, underweight, antenatal care attendance (ANC), postnatal care attendance (PNC), and educational level of women, unemployment rate, diarrhoea and vitamin A supplementation were extracted from the published reports of 2003, 2008 and 2014 DHSs. To determine if the time-fixed effect was needed when running the Fixed-Effect (FE) Poisson model, the combined effect of time dummies was tested. These were not found to be statistically significant, hence time-fixed effect was ignored in the final model. The region-fixed effect was included in the model. We performed all statistical analyses with Stata MP Version 15 (StataCorp, Texas) and $p<0.05$ were considered statistically significant.

Biological and dose-effect analysis

Given the higher coverage of malaria control interventions in the three northern regions, we explored evidence of biological explanation and dose-effect by comparing the trend in parasitaemia in children under five years old in the three northern regions with that in the rest of the country.

Results

Change in all-cause under-five child mortality

Ghana's under-five mortality decreased from 111 (95% CI 100-123) per 1,000 live births in 1993 through 80 (95% CI 69-92) in 2008 to 60 (95% CI 53-68) in 2014. (**Figure 3**) Significant reductions were observed in both urban and rural areas, but greater decreases were recorded in rural than urban (149 to 75 deaths per 1,000 live births). Mortality decreased among all wealth quintiles, but the highest reductions were in the fourth (108 to 55 deaths per 1,000 live births) and middle (111 to 61 deaths per 1,000 live births) quintiles. Mortality reductions were observed in all regions, but the greatest reductions were in the regions that had high malaria parasitaemia (according to MICS 2011) in under-five children: Upper West (188 to 92 deaths per 1,000 live births), Western (132 to 56 deaths per 1,000 live births), Brong-Ahafo (95 to 57 deaths per 1,000 live births), Northern (237 to 111 deaths per 1,000 live births), and Central (128 to 69 deaths per 1,000 live births). (**Table 1)**

Figure 3. Trend in under-five mortality in Ghana 1993 - 2014

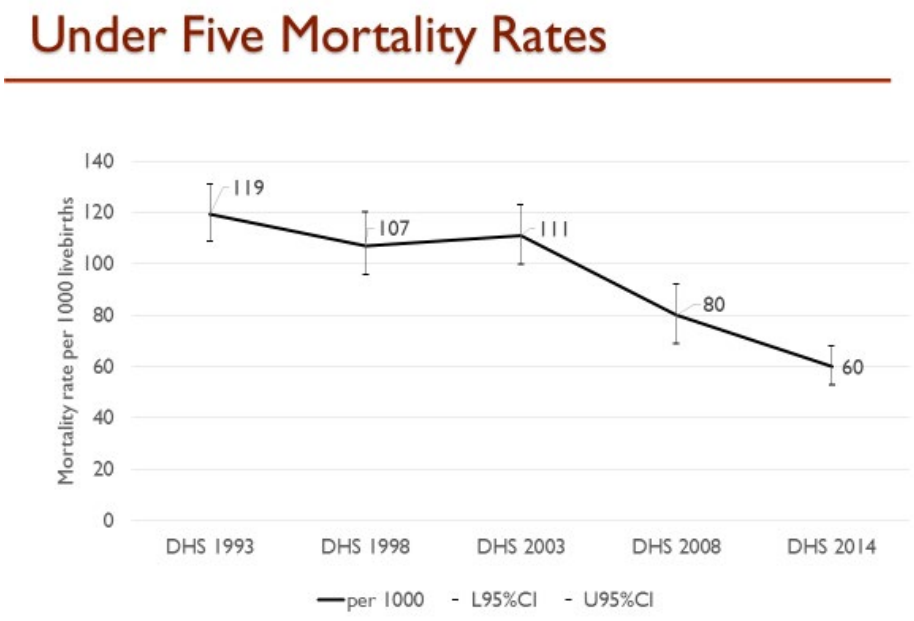


Table 1. Trends in All-Cause Mortality in Children Under Five Years of Age in Ghana, 1993-2014

Under-five mortality rates per 1,000 live births																
Background Characteristic	1989-1993 (1993 DHS)			1994-1998 (1998 DHS)			1999-2003 (2003 DHS)			2004-2008 (2008 DHS)			2010-2014 (2014DHS)			Relative Change
	#	*LCI	*UCI	#	LCI	UCI	#	LCI	UCI	#	LCI	UCI	#	LCI	UCI	2003 and 2014
Total (National)	119	109	131	107	96	120	111	100	123	80	69	92	60	53	68	-85
Residence																
Urban	90	77	105	77	64	92	93	79	108	75	63	88	64	55	74	-44
Rural	149	139	160	122	111	133	118	108	130	90	80	102	75	67	83	-58
Region																
Western	132	108	159	110	87	137	109	83	143	65	44	94	56	42	74	-97
Central	128	102	159	142	110	182	90	65	122	108	79	147	69	54	87	-31
Greater Accra	100	75	132	62	43	88	75	52	105	50	33	74	47	35	62	-59
Volta	116	97	139	98	76	126	113	91	140	50	30	83	61	46	81	-85
Eastern	93	72	120	89	71	111	95	73	122	81	54	120	68	54	86	-39
Ashanti	98	80	119	78	61	100	116	97	139	80	63	102	80	63	101	-46
Brong-Ahafo	95	77	116	129	94	174	91	71	115	76	54	106	57	45	71	-60
Northern	237	207	270	171	139	209	154	126	186	137	118	159	111	90	135	-39
Upper West	188	135	255	156	117	203	208	183	234	142	115	174	92	74	113	-127
Upper East	180	153	210	155	127	189	79	53	115	78	59	102	72	54	95	-9
Wealth Quintile																
Lowest	n/a	n/a	n/a	n/a	n/a	n/a	127	110	147	103	89	119	92	80	106	-39
Second	n/a	n/a	n/a	n/a	n/a	n/a	105	87	126	79	65	96	73	61	86	-44
Middle	n/a	n/a	n/a	n/a	n/a	n/a	111	92	132	102	81	127	61	49	75	-83
Fourth	n/a	n/a	n/a	n/a	n/a	n/a	108	90	129	68	52	88	55	44	69	-95
Highest	n/a	n/a	n/a	n/a	n/a	n/a	88	69	113	60	43	83	64	50	81	-39

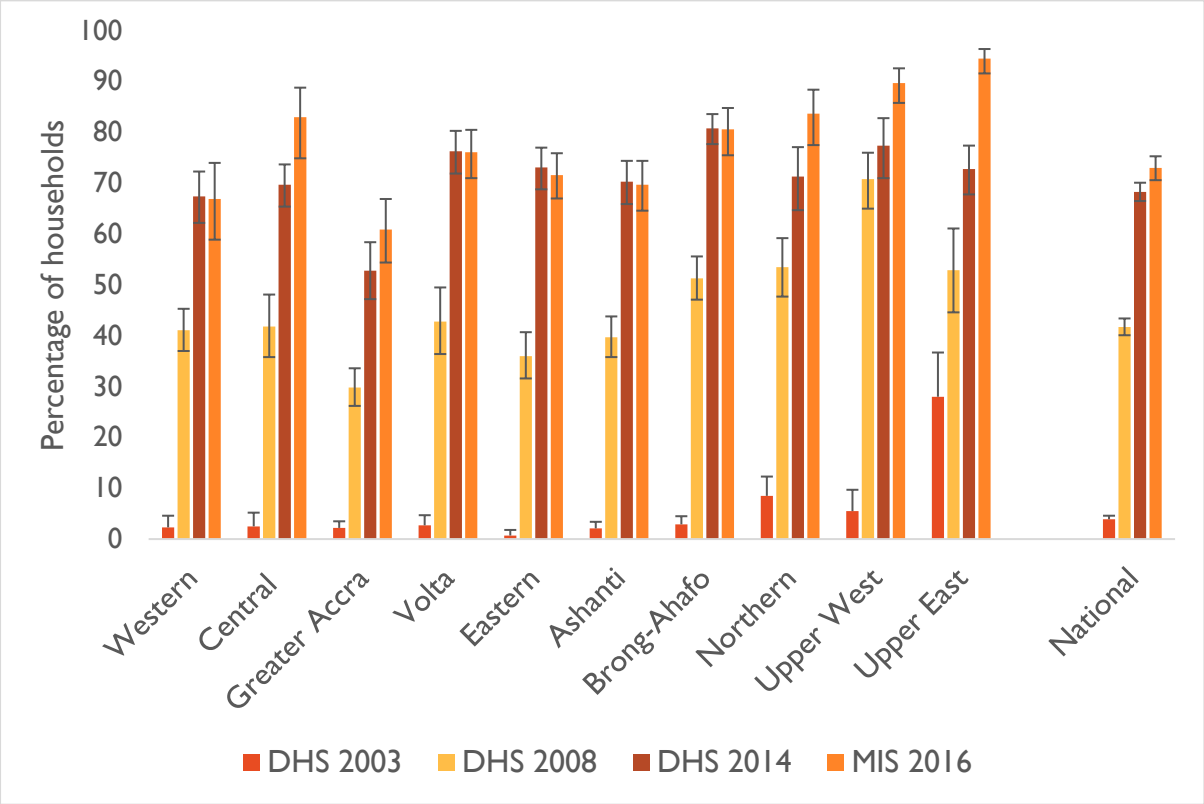
*LCI and UCL are lower and upper confidence intervals

Changes in intervention coverage

Ownership and Use of Insecticide-treated Nets

Household ownership of at least one ITN increased from 3.9% (95% CI 3.3 – 4.8) in 2003 to 73% (95% CI 70.6 – 75.3) in 2016. (**Figure 4**)

Figure 4. Percentage of households owning at least one ITN, by region 2003 - 2016



Access to ITNs, measured as at least one ITN per two persons in the household, increased from 1% (95% CI 0.8-1.3) in 2003 to 50.9% (95% CI 48-53.7) in 2016. Increases in ownership and access tended to be higher in the northern regions of the country than in the south (**Tables 2 and 3**)

Uptake of Intermittent Presumptive Treatment for Pregnant Women

The uptake of more than two doses of SP as part of IPTp rose from 27.5% in 2006 to 67.5% in 2014, and further increased to 78.0% in 2016. Uptake was similar across regions. (**Table 2**)

Table 2. Use of Intermittent Preventive Treatment Among Pregnant Women in Ghana by background characteristics, 2003-2016 i.e. Percentage of women age 15-49 with a live birth in the two years preceding the survey who received at least two doses of sulfadoxine-pyrimethamine for Intermittent Preventive Treatment (IPTp) during ANC visits during their last pregnancy

Background Characteristic	2003 DHS				2008 DHS				2014 DHS				MIS 2016				Percentage Point Change 2003-2016
	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	
Total (National)	0.8	0.4	1.4	1421	43.7	40	47.5	1178	67.5	64.5	70.3	2264	78	73.1	82.3	1285	77.2
Residence																	
Urban	0.7	0.2	2.1	477	46.3	40.2	52.4	455	68.2	63.3	72.7	1009	82.6	77.5	86.7	577	81.9
Rural	0.8	0.4	1.7	944	42.1	37.4	46.8	723	66.9	63.2	70.4	1255	74.3	67	80.5	708	73.5
Region																	
Western	0			128	45.5	34.2	57.3	111	67.3	57.9	75.6	217	77.3	68	84.5	101	77.3
Central	0.8	0.1	5.8	120	45.7	36.6	55.2	123	68.9	63.2	74	258	84.5	77.4	89.6	131	83.7
Greater Accra	1.6	0.4	5.9	150	29.4	20.3	40.4	133	59.3	50.1	68	332	78.7	68.6	86.3	207	77.1
Volta	1.6	0.4	6.4	134	59.8	50	68.8	107	65.1	56.6	72.7	177	75.1	62	84.8	110	73.5
Eastern	0			142	40.8	30.8	51.5	105	64.2	57.3	70.5	206	89.2	80.9	94.2	100	89.2
Ashanti	1	0.2	4.2	245	50.8	40.5	61.1	215	73.2	65.4	79.9	397	79.6	69.4	87.1	238	78.6
Brong-Ahafo	0.3	0	1.8	158	63.7	48.5	76.5	107	80.7	72.1	87.2	214	85	77.3	90.5	111	84.7
Northern	0			208	27.9	20.7	36.3	177	60.7	49	71.3	304	61	48	72.6	211	61
Upper West	1.5	0.4	5.6	49	52.5	42.3	62.6	36	73.8	67.4	79.4	64	82.2	76.1	87	30	80.7
Upper East	2.6	0.7	8.7	86	26	15.7	39.9	63	67.7	58.8	75.5	95	90.8	81.4	95.7	45	88.2
Wealth Quintile																	
Lowest	0.7	0.2	2.5	373	31.2	25.2	37.8	283	64.7	57.4	71.4	519	69.1	58.9	77.7	282	68.4
Second	0.7	0.2	2	319	42.6	35.9	49.5	261	70.8	65.2	75.8	474	74.9	66.8	81.6	269	74.2
Middle	1.1	0.3	3.6	284	50.3	42.6	58	222	64.1	58.8	69.1	433	78.3	71.4	83.9	265	77.2
Fourth	0.4	0.1	2.8	235	49.2	41.5	57	243	63.2	56.5	69.4	444	83.5	76.4	88.8	237	83.1
Highest	1.1	0.3	4.3	210	49.8	40.6	59	169	75.6	68.9	81.2	393	86.6	77.2	92.5	231	85.5
Age (in years)																	
15-19	0			96	44.2	32.7	56.4	80	66.8	55.5	76.4	143	79.3	64.8	88.8	91	79.3
20-24	1.4	0.5	3.8	308	43.9	36.9	51.1	278	61.3	55.4	66.8	441	73.3	64.8	80.4	289	71.9
25-29	1.5	0.7	3.4	384	44.5	38	51.1	342	69.8	64.2	74.8	614	77.1	67.9	84.3	314	75.6
30-34	0			296	46.6	39.5	53.8	223	70.4	65.2	75.2	516	82	74.3	87.8	313	82
35-39	0			225	42.1	33.9	50.7	169	67.4	60.2	73.8	379	82	73.8	88	198	82
40-44	1.3	0.2	8.9	74	38.4	26.7	51.7	68	65.7	56.2	74.1	137	72.5	55.6	84.7	72	71.2
45-49	0			38	21.3	7.3	48.3	17	73.3	58.7	84.1	34	66.2	36.9	86.8	8	66.2

Note: n=Weighted number of women (denominator); IPTp: Intermittent Preventive Treatment during pregnancy is preventive treatment with two or more doses of SP/Fansidar**.**

Use of ITNs in children under five also increased from 3.9% (95% CI 3.1-4.9) in 2003 to 52.2% (95% CI 48.8-55.5) in 2016. (**Figure 5)** ITN use by pregnant women also increased from 2.7% (95% CI 1.6-4.6) in 2003 to 50% (95% CI 42.3-57.6) in 2016. (**Figure 6)** Increases in ITN use for both under-five children and pregnant women tended to be higher in the northern regions of the country than the rest of the country. (**Figures 5 and 6, Northern, Upper West and Upper East Regions**)

Figure 5. Use of insecticide-treated net the night before the survey by under-five children by regions 2003-2016

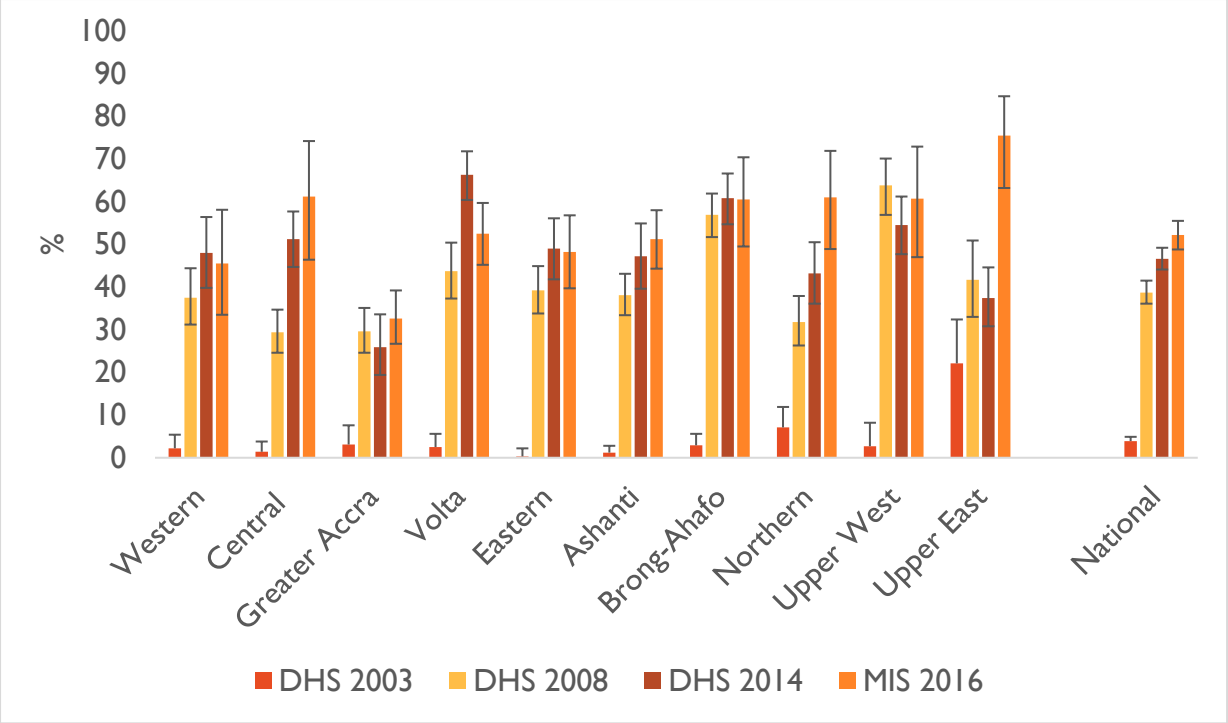
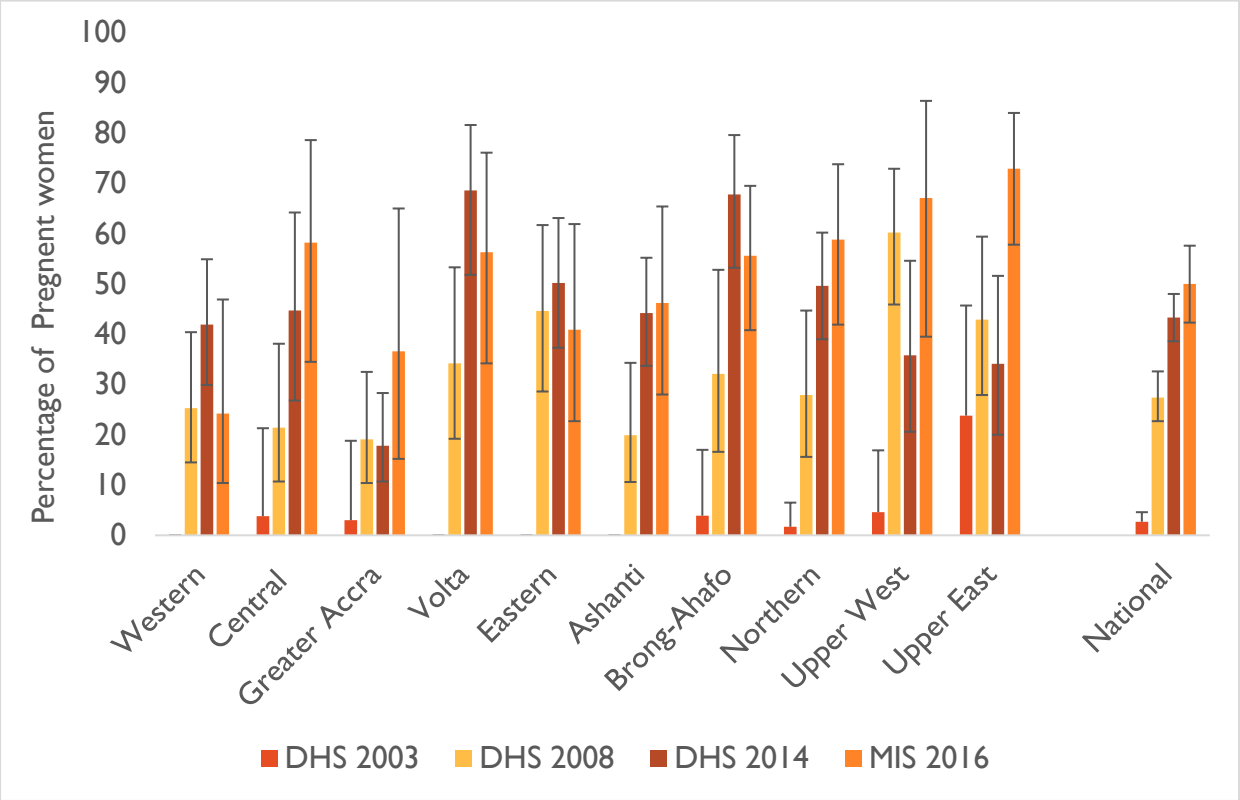


Figure 6. Use of insecticide-treated nets by pregnant women by regions 2003-2016



Case management

The percentage of children under 5 years old with recent fever for whom advice or care was sought increased from 51% (95% CI 45.5-55.9) in 2008 to 72% (95% CI 64.5-78.1) in 2016. Among children with fever for whom care was sought and who received antimalarials, the percentage who reported receiving the recommended first-line treatment for uncomplicated malaria, increased from 48% (95% CI 39.2-56.54) in 2008 to 78% (95% CI 72.1-83.3) in 2014 but decreased to 59% (95% CI 50-66) in 2016. The greatest decreases between 2014-2016 were among the poorest quintiles (75-48% lowest; 84-58% second; 77-49% middle) and in rural areas (81-59%).

Among all children with reported fever in the previous two weeks, the proportion reported to have received a finger or heel stick (proxy for receiving a malaria diagnostic test) was 34.2% (95% CI 29.6-39.4) in 2014 and 30.3% (95% CI 25.6-35.4) in 2016.

Major non-malaria factors

Specific child health indicators that registered improvements over the period of evaluation are: prevalence of underweight, defined as low weight for age, among children less than 5 years old

decreased from 17.6% in 2006 to 11.0% in 2014. In the same period, the uptake of vitamin A supplementation rose from 60.2% to 65.2% and the proportion of children who completed the WHO-recommended schedule of basic immunization by age 12 months rose from 64.4% to 71.1%. Rates of exclusive breastfeeding remained stable from 2006 (54.4%) to 2014 (52.3%). Annual GDP per capita increased 121% from $US 625 in 2003 to $US 1,384 in 2016.

Indoor Residual Spraying (IRS)

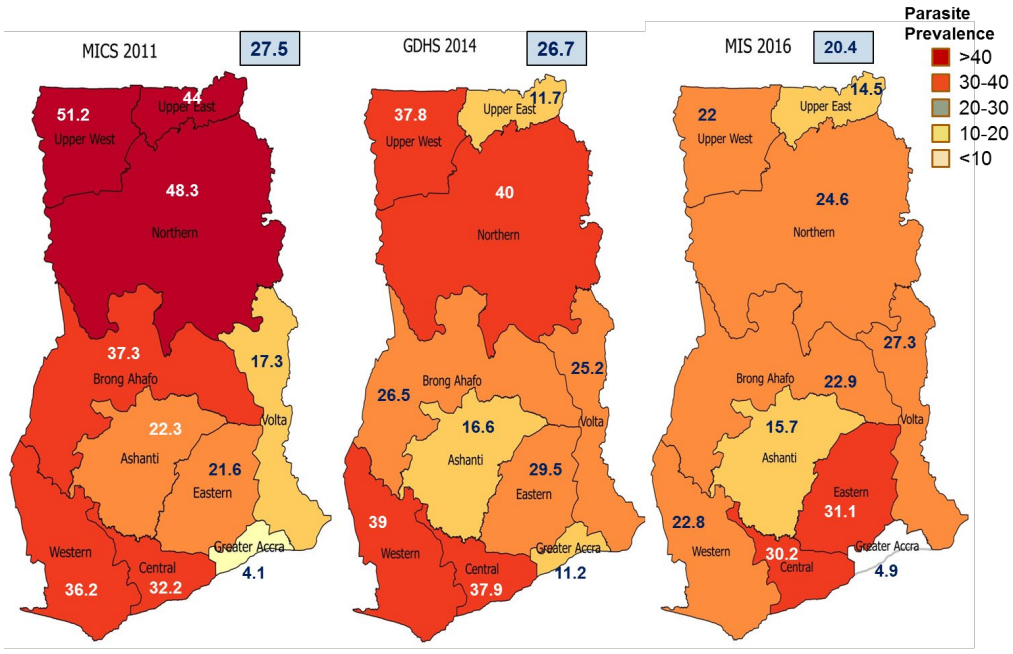
Following IRS implementation, malaria parasitaemia among under-five children decreased as follows: Upper West Region, 51.2% in 2011 to 37.8% in 2014 to 22% in 2016; Upper East Region, 44% in 2011, 11.7% in 2014, and 15.5% in 2016; Northern Region (where a subset of districts was sprayed), 48.3% in 2011, 40% in 2014, and 24.6% in 2016. (**Figure 7**).

Trends in morbidity

Malaria Prevalence and Anaemia in Children

Malaria prevalence measured by microscopy among under-five children decreased from 27.5% in 2011 to 26.7% in 2014, and to 20.6% in 2016. (**Table 6**) Decreases occurred in all regions, wealth quintiles, age categories, and residence (urban or rural). No parasitaemia data are available for a 2006 baseline.

Figure 7. National and regional prevalence of parasitaemia among children 6 – 59 months old in Ghana: 2011 to 2016



The prevalence of severe anaemia (Hb<8g/dL) in children under five years old also decreased from 14.3% (95% CI 17-21.4) in 2003 to 6.9% (95% CI 5.4-8.7) in 2016. Significant decreases were noted across all wealth quintiles (greatest decrease in poorest), age categories, urban/rural areas, and regions. (**Table 3**)

Table 3. Prevalence of Severe Anaemia in Children Aged 6-59 Months in Ghana by background characteristics

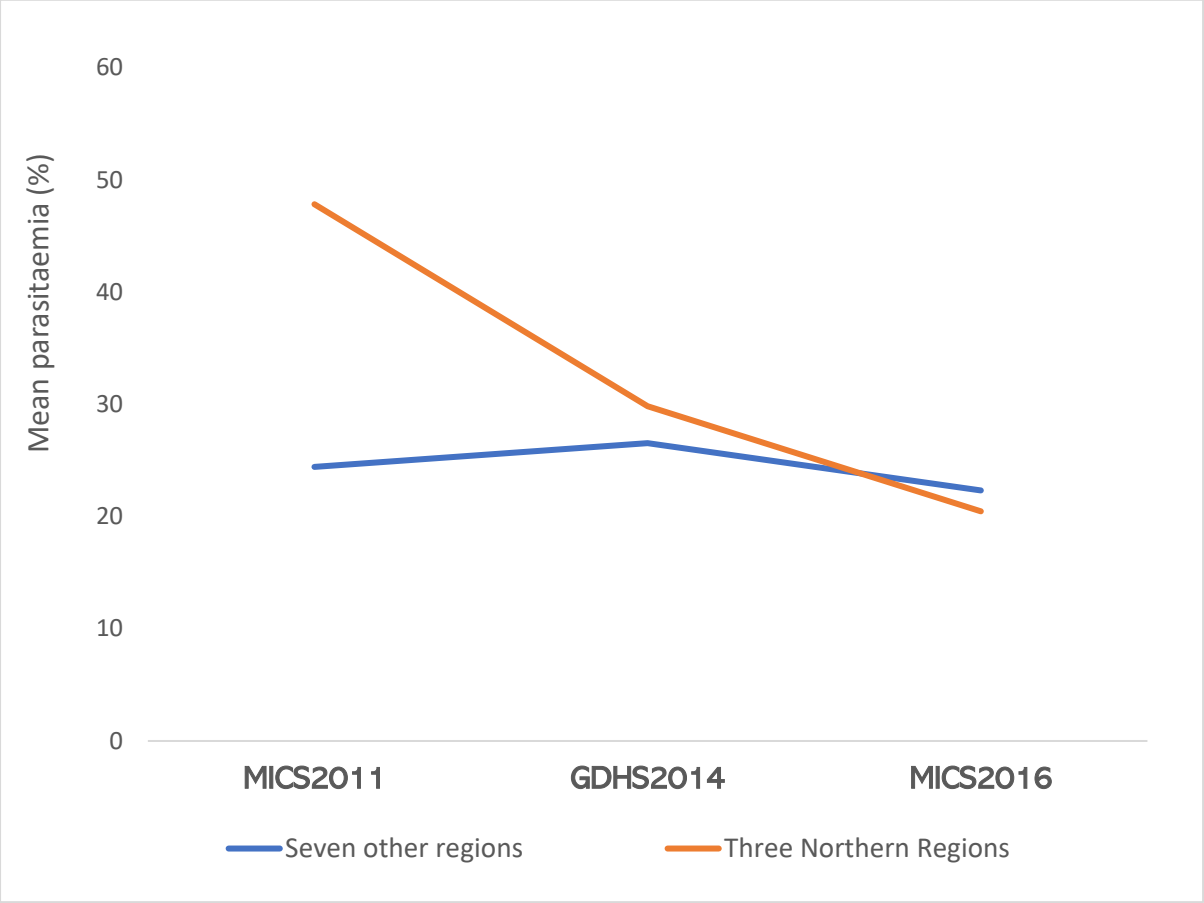
Background Characteristic	2003 DHS				2008 DHS				2014 DHS				MIS 2016				Percentage Point Change 2003-2016
	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	
Total (National)	14.3	12.8	15.9	2992	19.1	17	21.4	2342	8.3	7	9.9	2568	6.9	5.4	8.7	2874	-7.4
Residence																	
Urban	9	7.1	11.3	984	13.1	10.4	16.4	894	4.4	3	6.6	1180	4.1	2.2	7.4	1276	-4.9
Rural	16.9	15	18.9	2008	22.8	20	25.9	1448	11.6	9.7	13.9	1388	9.1	7.1	11.7	1598	-7.8
Region																	
Western	15.4	11.1	21.2	293	26.5	19.3	35.3	221	8	5.3	11.8	273	3.9	1.6	9.3	213	-11.5
Central	14.9	10.8	20.2	267	19.2	14	25.7	225	10.7	6.6	17	304	14	8	23.4	281	-0.9
Greater Accra	8	4.7	13.1	324	6	3	11.9	267	4.2	1.4	12.1	389	1.3	0.3	4.6	406	-6.7
Volta	10.2	6.6	15.6	255	16.7	11.5	23.7	203	8.4	5.8	12	189	8.7	5.5	13.5	217	-1.5
Eastern	11.8	8.4	16.4	292	11.2	6.9	17.8	211	5.8	3.3	9.8	238	8.6	5.1	14.1	224	-3.2
Ashanti	14.6	10.8	19.3	553	20.8	14.9	28.2	460	5	2.6	9.5	432	3.7	1	12.9	656	-10.9
Brong-Ahafo	16.8	12.8	21.8	333	19.1	13.6	26.3	250	6.4	3.7	10.8	260	4.4	2	9.4	233	-12.4
Northern	20.1	15.3	26	403	27.8	22.7	33.5	332	18.2	14	23.4	313	12.4	9.1	16.7	464	-7.7
Upper West	11.7	8.1	16.6	86	31.2	24.5	38.8	63	16.5	11.1	23.8	66	9.1	5.9	13.8	75	-2.6
Upper East	15	10.1	21.6	186	15	10.3	21.3	109	6.7	4.1	10.7	105	7.4	4.9	11	105	-7.6
Wealth Quintile																	
Lowest	19.9	17	23	774	26.2	22.5	30.2	585	15.8	12.7	19.6	588	12.1	9.8	14.8	645	-7.8
Second	16.5	13.5	19.9	660	23	19	27.5	543	12.6	9.7	16.2	530	12.1	7.8	18.3	593	-4.4
Middle	13.7	11	17	597	20.4	16.4	25.2	425	7.1	4.5	10.9	523	5	3.2	7.8	581	-8.7
Fourth	11.3	8.3	15.1	521	13.8	10.4	18.2	463	3.2	1.8	5.6	483	2.6	1.5	4.8	588	-8.7
Highest	5.4	3.3	8.6	441	5.7	3.4	9.4	326	0.3	0	1.9	445	0.7	0.2	2.8	466	-4.7
Age (in months)																	
6-11 months	20.8	16.3	26.2	348	28.4	22.7	34.9	245	9.6	6.4	14	260	10	6.2	15.7	310	-10.8
12-23 months	23.1	19.7	26.8	661	24.3	20.5	28.5	521	14	10.6	18.2	587	11.8	9	15.5	648	-11.3
24-35 months	13.6	10.8	16.9	635	23.7	19.4	28.5	492	7.3	5.3	9.9	573	6.3	4.5	8.7	670	-7.3
36-47 months	10.1	8	12.7	716	12.7	9.5	16.8	517	8.5	6	11.9	570	4.5	2.8	7.1	591	-5.6
48-59 months	6.9	5.1	9.2	632	12.2	9.4	15.6	566	2.9	1.8	4.6	578	3.2	1.8	5.9	655	-3.7
6-23 months	22.3	19.5	25.4	1009	25.6	22.2	29.3	767	12.6	9.8	16.1	847	11.3	8.5	14.8	958	-11
24-59 months	10.2	8.8	11.8	1983	15.9	13.7	18.4	1575	6.2	5	7.7	1721	4.7	3.6	6.1	1916	-5.5

Note: n=Weighted number of children (denominator)

Dose-response relationship

The decline in malaria parasitaemia among children less than 5 years old in the three northern regions was much faster than it was for the rest of the country. It was an average decline of 13.7% per year compared to 1.1% in the rest of the country) from 2011 to 2016. Although parasitaemia level was approximately twice as high in the northern regions as in the rest of the country in 2011, by 2016, the malaria parasitaemia levels in these regions were comparable (20% versus 22%). (**Figure 8**)

Figure 8. Mean percentage of children less than 5 years old with malaria parasites at the time of the survey in the three northern regions versus the remaining seven regions, 2011-2016



***The three northern regions are the Upper West Region, Upper East Region and the Northern Regions**

Relationship between household ownership and use of ITN and under-five mortality

Individual level analyses

All-cause mortality among under-five children was consistently lower among households with at least one ITN at the time of the survey, compared to households with no ITN at the time of the survey for each of the surveys studied. The results from 2014 DHS showed that there were approximately 8 (95% CI: 6-10) deaths per 1000 person-years among children who live in households with at least one ITN compared to 10 (95% CI: 6-20) deaths per 1000 person-years among children who live in households with no ITN **(Table 4).**

Table 4: Deaths among children <5 years old who live in households with at least one ITN or no ITN at the time of the survey, by person-time observed or number of live births: 2003, 2008 and 2014 DHS.

	2003 DHS Ref. period: 1999-2003	**2008 DHS Ref. period: 2004-2008**	**2014 DHS Ref. period: 2010-2014**	**2003-2014 DHS Ref. period: 1999-2014**
Cumulative deaths per 1000 person-years among children <5 years old				
Household with at least one ITN	14.1 (9.9- 20.7)	11.6 (8.9-15.4)	7.5 (5.9-9.6)	9.8 (8.3-11.6)
Household with **no** ITN	18.7 (15.3-23.0)	18.7 (13.1-27.6)	10.2 (5.8-20.0)	17.1 (14.420.4)
Overall	17.6 (14.7 -21.1)	13.7 (11.1-17.2)	8.0 (6.4-10.2)	12.7 (11.3-14.3)
Deaths among children <5 years old per 1000 live births				
Household with at least one ITN	104.0 (80.0-134.7)	73.2 (61.6-87.0)	58.5 (50.7-67.4)	68.2 (61.6-75.6)
Household with no ITN	109.5 (94.8- 126.4)	109.2 (82.3-144.0)	75.3 (55.4-101.9)	101.8 (90.4-114.6)
Overall	108.1 (95.2- 122.6)	83.3 (71.5-96.8)	61.6 (54.1-70.1)	80.7 (74.7-87.2)
Total number of children sampled	3,844	2,992	5,884	12,720
Person-time at risk for children who live in households with at least one ITN (child-years)	1,948.0	4,614.5	10,569.5	12,380,396.0
Person-time at risk for children who live in households with at no ITN (child-years)	6,223.0	1,958.2	2,487.5	8,005,462.5

Data source: Children's Data - Children's Recode (KR) for 2003, 2008 and 2014 DHS: (www.dhsprogrammme.com). *Ref: Reference period.*

Estimates obtained using a modified Poisson model showed that among children < 5 years old, a child's reported or inferred use of an ITN was significantly associated lower mortality during each time period assessed. Household ownership of an ITN was non-significantly associated with lower all-cause mortality during each period assessed. The sensitivity analysis based on the Cox-proportional hazard model showed similar results **(Table 5)**

Table 5: Association between ITN ownership and use at the time of the survey and all-cause under five mortality during the 5 years preceding the survey, Ghana, 2003-2104

	2003 DHS Ref. period: 1999-2003	2008 DHS Ref. period: 2004-2008	2014 DHS Ref. period: 201042014	2003-2014 DHS Ref. period: 1999-2014
	aRR (95%CI)	aRR (95%CI)	aRR (95%CI)	aRR (95%CI)
Modified Poisson model				
Child use of ITN (ref children not using ITN)*	0.56*(0.36-0.88)	0.39***(0.25-0.60)	0.56**(0.40-0.78)	0.52***(0.41-0.65)
Child in household owning at least one ITN (Ref. child in household not owning net)	0.86 (0.61-1.23)	0.70 (0.48-1.04)	0.84 (0.58-1.23)	0.83 (0.66-1.03)
Cox-proportional hazard model				
Child use of ITN (ref child not using ITN)*	0.53**(0.34-0.80)	0.38**(0.26-0.57)	0.57***(0.42-0.78)	0.51***(0.41-0.64)
Child in household owning at least one ITN (Ref child in household not owning net)	0.84 (0.61-1.17)	0.69* (0.48-0.98)	0.88 (0.54-1.45)	0.81 (0.66-1.00)

P-value notation: * indicates p<.05; ** indicates p<.01;*** indicates p<.001. GDHS: Ghana Demographic Health Survey, aRR: Adjusted Relative Risk estimates based on all births in the 1-59 months preceding the date of interview; N=3760 for the 2003 GDHS, N=2933 for the 2008 GHDS, N= 5847 for the 2014 GDHS, N=12720 for the combined dataset (2003-2014). Adjusted relative risk estimates control for characteristics of the household (sex and age of household head, urban residence, wealth quintile, region, household size, access to an improved water source, and access to an improved non-shared toilet), characteristics of the mother (current age of the mother, age of mother at first child's birth, marital status, and level of education) and characteristics of the child (sex, birth order, and multiple births). For the GDHS 2003, 2008, 2014 and the combined dataset (2003-2014), Body Mass Index, Preceding birth interval, Antenatal care attendance and Tetanus vaccination status were not included in the adjusted model because of empty cells. We further adjusted for time period in fitting the model based on the full dataset (2003-2014 combined).
*for children who died we used mother ITN use as proxy for children ITN use.

Ecological (regional) level analyses:

An increase in percentage of households with at least one ITN was associated reducing under-five mortality rate. The results from the fixed-effect Poisson model with robust standard error showed that a unit increase in the percentage of households with at least one ITN is associated with a 0.49% reduction in under-five mortality rate, controlling for other time-varying covariates in the model (adjusted relative risk [aRR] 0.995, 95% CI: 0.992-0.998). (**Table 6**).

Table 6: Ecological analysis of the effect of ITN ownership on all-cause under-five mortality using fixed-effect modified Poisson with robust standard error.

	aRR (95% CI)
Predictor	
Household ownership of at least one ITN	**0.995** (0.992-0.998)**
Co-variates	
Underweight	1.005 (0.995-1.016)
No ANC	1.010 (0.974-1.046)
No PNC	1.002 (0.997-1.01)
No Education	0.982* (0.967-0 .998)
Unemployment	1.005 (0.996-1.015)
No vaccination	1.014 (0.961-1.070)
Diarrhea	1.019** (1.005-1.034)
Vitamin A supplement	1.004 (0.998-1.009)

Data source: 2003, 2008, 2014 Ghana Demographic Health Survey Report; Abbreviation: aRR, Adjusted Relative Risk -**Definitions: Underweight measured using w**eight-for-age which is a composite index of height-for-age and weight-for-height. It considers both acute and chronic malnutrition. Children whose weight-for-age is below -2 SD from the median of the reference population are classified as underweight; No **ANC**: % of women 15-49 with a live birth in the 5yrs preceding the survey with no ANC**; No PNC**: % of women 15-49 with a birth in the 5yrs preceding the survey with no PNC check; No **Education**: Percent of women age 15-49 with no level of schooling; **Unemployment:** % of women 15-49 who were not employed in the 12 months preceding the survey; **No vaccination:** % of children 12-23 months who didn't received any vaccination at any time before the survey**; Diarrhea**: % of children under five years with diarrhea in 2 weeks preceding the survey; Time fixed effect was excluded from the final model since the combined effect of time was not statistically significant **P-value notation**: ***p<0.001, **p<0.01, *p<0.05.

Discussion

Decline in under-five mortality in Ghana has aligned very closely with the expanded coverage of other malaria control interventions. A 46% reduction in under-five mortality was observed along with 44.3, 11.0 and 50.5 percentage point increase ITN use by children aged less than 5 years, access to the first-line antimalarial for children with fever and uptake of at least 2 doses of ITP. Malaria parasite prevalence in under-five children also recorded by 7.1 percentage points.

In this study, we applied a range of plausibility analyses that included using regression analysis that related household ITN possession and use and death of an under-five child within the household. We found a significant association that implied that possession and use of ITN was associated with reduced mortality. Based on the robustness and concurrence of the findings using different methodological approaches, we believe that the significant increase in ITN use in Ghana from 2006 to 2014 contributed substantially to decline in under-five mortality over the same period. Our finding that a unit increase in the percentage of households with at least one ITN is associated with a 0.49% reduction in the risk of under-five mortality rate is consistent with published evidence on the effect of ITN reducing malaria morbidity and mortality in sub-Saharan Africa.[3,32-34] It strengthens evidence for the continued deployment of ITN in Ghana and malaria-endemic sub-Saharan Africa.

In our analysis, we found that malaria parasitaemia in under-five children in the three northern regions declined at a rate more than 10 times that observed in the rest of the country. This finding lends credence to the case of impact of malaria control interventions in two important ways. It represents a dose-response effect given the concentration of activities in the three northern regions and the evident positive effect this has had on the coverages of the various interventions. The findings also represent consistency with theoretical and biological models that explain how increased coverage in interventions should lead to less malaria parasitaemia and this ultimately leading to reduced overall mortality. Unfortunately, data quality precluded analysis using routine health service data on reported malaria cases in the country.

Our finding that coverage in IPTp was less well correlated with reduction in under-five mortality is consistent with the theoretical consideration that prevention of malaria in pregnant women was not quite as proximal to under-five mortality as a child sleeping under an ITN or child being given ACT to treat fever.

Malaria control activities in Ghana have led to remarkable increases in the coverage of the major interventions. The findings in this study are consistent with finding from an analysis of routine Ghanaian health service data. In an analysis of records of malaria cases and deaths and availability of ACT in 88 health facilities across the country, Aregawi et al found that compared to the period before 2005, the number of outpatient **malaria** cases declined by 57% between 2005-2015. While the number of malaria fell significantly by 65%, the number of deaths among children aged less than 5 years decreased by 50%.[21] In analysis using the 2008 DHS, Afoakwah et al demonstrated that under-five mortality among children who sleep under treated bed nets was about 18.8% lower than among children who do not sleep under treated bed nets.[35]

In this study we found that uptake of interventions was particularly high in the three northern regions. Although the period of substantial increase in the coverage of malaria control interventions has coincided with the remarkable decline in under-five mortality, it needs to be acknowledged that evidence of decline in under-five mortality began before the period when malaria interventions were scaled-up. This suggests the existence of other important contributory factors.

A major limitation in ecological analysis is the fact that it does not establish causality. The accepted principle is therefore to build the case of possible causal relationship on the basis of evidence of correlation, consistency (internal and external), biological plausibility and dose-effect. [36] The case is further strengthened when the relationship between interventions and effects holds up across different populations and epidemiological zones and is reasonably consistent with findings made in similar other settings. [4]

Our efforts at relating the scale-up of malaria control interventions to decline in under-five mortality has been complex for a number of well-described limitations. First, all the available data is derived from observational studies (surveys) and not from purposefully-designed experiments. There was thus mismatch (in some cases) between the period covered by the available data on coverages and under-five mortality. For example, while under-five mortality trend could be traced to 1993 to establish a clear decline trend, nationally-representative data on malaria parasitaemia existed only from 2011. Similarly, IRS was deployed in specific selected districts. This situation was encountered in previous similar work and led to an evaluation of complex interventions assuming a body of science on its own. [37-39]

Conclusion

The scale-up of malaria control interventions in Ghana between 2003 and 2016 coincided with substantial decline in under-five mortality during the same period. Our analyses have demonstrated close association between the two events, with scale-up in the use of ITNs and ACTs being the most firmly-correlated. Our findings support the case of impact and the need to sustain support for malaria control interventions in Ghana.

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Annex: Supplementary Materials

Table 1. Trends in All-Cause Mortality in Children Under Five Years of Age in Ghana, 1993-2014

Background Characteristic	2003 DHS			2008 DHS			2014 DHS			Relative Change
	#	LCI	UCI	#	LCI	UCI	#	LCI	UCI	2003 and 2014
Total (National)	111	100	123	80	69	92	60	53	68	-85
Residence										
Urban	93	79	108	75	63	88	64	55	74	-44
Rural	118	108	130	90	80	102	75	67	83	-58
Region										
Western	109	83	143	65	44	94	56	42	74	-97
Central	90	65	122	108	79	147	69	54	87	-31
Greater Accra	75	52	105	50	33	74	47	35	62	-59
Volta	113	91	140	50	30	83	61	46	81	-85
Eastern	95	73	122	81	54	120	68	54	86	-39
Ashanti	116	97	139	80	63	102	80	63	101	-46
Brong-Ahafo	91	71	115	76	54	106	57	45	71	-60
Northern	154	126	186	137	118	159	111	90	135	-39
Upper West	208	183	234	142	115	174	92	74	113	-127
Upper East	79	53	115	78	59	102	72	54	95	-9
Wealth Quintile										
Lowest	127	110	147	103	89	119	92	80	106	-39
Second	105	87	126	79	65	96	73	61	86	-44
Middle	111	92	132	102	81	127	61	49	75	-83
Fourth	108	90	129	68	52	88	55	44	69	-95
Highest	88	69	113	60	43	83	64	50	81	-39

Table 2. Percentage of households with at least one insecticide-treated net by background characteristics 2003-2016

Percentage of households with at least one insecticide-treated net (ITN) among all the households interviewed, by background characteristics

Background Characteristic	2003 DHS				2008 DHS				2014 DHS				MIS 2016				Percentage Point Change 2003-2016
	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	
Total (National)	3.9	3.3	4.6	6,251	41.7	40.1	43.4	11,777	68.3	66.5	70.1	11,835	73	70.6	75.3	5,841	69.1
Residence																	
Urban	2.8	2.1	3.8	2,870	34.7	32.7	36.8	5627	60.1	57.4	62.7	6503	65.3	62.2	68.3	3195	62.5
Rural	4.8	3.9	5.9	3,381	48.1	45.7	50.6	6150	78.4	76.2	80.4	5332	82.4	79.6	84.8	2646	77.6
Region																	
Western	2.3	1.2	4.6	612	41.1	37	45.3	1184	67.4	62.2	72.3	1298	66.9	58.9	74	482	64.6
Central	2.5	1.2	5.2	587	41.8	35.8	48.1	1279	69.7	65.4	73.7	1180	83	74.9	88.8	646	80.5
Greater Accra	2.2	1.4	3.5	890	29.8	26.2	33.6	1951	52.8	47.2	58.4	2457	60.9	54.4	66.9	1177	58.7
Volta	2.7	1.5	4.7	538	42.8	36.4	49.5	991	76.3	71.9	80.3	1015	76.1	71	80.5	423	73.4
Eastern	0.7	0.3	1.8	732	36	31.6	40.7	1260	73.1	68.8	77	1255	71.6	67	75.9	574	70.9
Ashanti	2.1	1.3	3.4	1313	39.7	35.8	43.8	2263	70.3	65.9	74.4	2216	69.7	64.6	74.4	1278	67.6
Brong-Ahafo	2.9	1.9	4.5	665	51.3	47.1	55.6	1154	80.8	77.7	83.6	1028	80.6	75.5	84.8	490	77.7
Northern	8.5	5.8	12.3	487	53.5	47.7	59.2	928	71.3	64.7	77.1	742	83.7	77.5	88.4	464	75.2
Upper West	5.5	3.1	9.7	147	70.8	65	76	228	77.4	71	82.8	265	89.7	85.8	92.6	126	84.2
Upper East	28	20.7	36.7	280	52.9	44.6	61.1	540	72.8	67.8	77.4	378	94.5	91.6	96.4	180	66.5
Wealth Quintile																	
Lowest	7.8	5.9	10.2	971	50.2	46.5	53.8	1813	79.6	76.6	82.2	1600	86.3	82.8	89.2	906	78.5
Second	2.7	1.8	4	1168	46	42.7	49.3	2250	77.9	75.1	80.5	2211	81	77.2	84.3	1143	78.3
Middle	3	2.1	4.2	1315	40.1	37.2	43.1	2548	69.7	66.7	72.6	2647	73.3	70.6	75.8	1203	70.3
Fourth	2.7	1.9	3.7	1452	36.5	34	39	2646	62.9	59.9	65.7	2686	66.3	62.3	70	1310	63.6
Highest	4.4	3.3	5.9	1345	39	36.2	41.9	2520	57.9	54.3	61.4	2690	63.2	58.7	67.4	1278	58.8

Note: n=Weighted number of households (denominator); An insecticide-treated net (ITN) is (1) a factory-treated net that does not require any further treatement (LLIN) or (2) a pretreated net obtained within the past 12 months of (3) a net that has been soaked with insecticide within the past 12 months.

Table 3. Percentage of households with at least one insecticide-treated net for every two persons by background characteristics 2003-2016

Percentage of households with at least one ITN for every two people, by background characteristics and survey year, Ghana

Background Characteristic	2003 DHS				2008 DHS				2014 DHS				MIS 2016				Percentage Point Change 2003-2016
	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	
Total (National)	1	0.8	1.3	6213	17	15.9	18.1	11716	45.2	43.5	46.9	11743	50.9	48	53.7	5770	49.9
Residence																	
Urban	0.8	0.5	1.3	2852	14.8	13.4	16.4	5596	41.3	38.8	43.8	6444	45.8	42	49.6	3151	45
Rural	1.2	0.8	1.7	3361	18.9	17.3	20.7	6120	50	47.7	52.3	5299	57	53.4	60.5	2619	55.8
Region																	
Western	0.7	0.2	2.2	607	15.7	13.3	18.5	1174	44.8	40.3	49.4	1293	46.1	40.5	51.9	472	45.4
Central	1.5	0.7	3.4	585	19.1	15	24.1	1265	44.4	41.1	47.9	1167	61.7	52.3	70.4	643	60.2
Greater Accra	0.7	0.3	1.7	885	12.6	10.2	15.6	1935	35.1	30.2	40.4	2431	41.9	34.6	49.4	1151	41.2
Volta	0.7	0.2	2.1	533	18.4	13.8	24.1	987	55.2	49.8	60.4	1008	52.3	45.4	59.2	418	51.6
Eastern	0.2	0	1.5	727	13.5	10.7	16.9	1258	52	47.5	56.4	1249	44.6	40.3	49	571	44.4
Ashanti	0.6	0.3	1.3	1304	15.9	13.8	18.3	2254	46.7	42.9	50.6	2194	47.2	40.5	54	1267	46.6
Brong-Ahafo	1	0.5	2	661	22.2	19.3	25.4	1149	59	55.1	62.7	1021	58	53.1	62.8	482	57
Northern	1.4	0.7	2.9	485	18.2	14.6	22.4	926	37.5	31.7	43.6	740	59.9	54.4	65.3	461	58.5
Upper West	1.5	0.7	3	145	28.9	25.1	33	228	42.6	37.4	47.8	263	65.2	57.5	72.2	125	63.7
Upper East	6	3.6	9.8	280	22	17	27.9	539	36.5	31.6	41.6	376	72.4	65.2	78.6	179	66.4
Wealth Quintile																	
Lowest	0.7	0.4	1.3	970	15.4	13.2	17.9	1810	42.6	39.6	45.6	1599	59.2	54.1	64.2	902	58.5
Second	0.8	0.4	1.5	1161	18	15.8	20.4	2236	50.9	48	53.7	2197	59.6	55.2	63.8	1129	58.8
Middle	1.1	0.6	1.9	1307	17	15	19.3	2535	48.7	45.8	51.6	2622	50.5	46.7	54.2	1181	49.4
Fourth	1.1	0.7	1.7	1436	15.2	13.5	17.1	2632	42.9	39.8	46.1	2661	45.1	40.8	49.4	1300	44
Highest	1.4	0.8	2.4	1338	19	16.8	21.4	2502	41.1	37.5	44.8	2665	43.4	38.2	48.9	1258	42

Note: n=Weighted number of households (denominator); An insecticide-treated net (ITN) is (1) a factory-treated net that does not require any further treatement (LLIN) or (2) a pretreated net obtained within the past 12 months or (3) a net that has been soaked with insecticide within the past 12 months.

Table 4. Use of Insecticide-treated Nets Among Under Five Children in Ghana by background characteristics, 2003-2016

Background Characteristic	2003 DHS				2008 DHS				2014 DHS				MIS 2016				Percentage Point Change 2003-2016
	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	
Total (National)	3.9	3.1	4.9	3593	38.7	36.1	41.5	2906	46.6	44.1	49.2	5801	52.2	48.8	55.5	3234	48.3
Residence																	
Urban	3.8	2.5	5.8	1202	32.6	29.6	35.6	2229	36.1	32.7	39.6	2639	40.8	36.3	45.4	1466	37
Rural	4	2.9	5.3	2391	42.6	39.9	45.3	3561	55.4	51.7	59	3163	61.7	56.5	66.7	1768	57.7
Region																	
Western	2.2	0.9	5.4	346	37.5	31.2	44.4	534	48	39.8	56.4	583	45.5	33.5	58.1	241	43.3
Central	1.4	0.5	3.8	306	29.4	24.6	34.7	569	51.2	44.7	57.7	621	61.2	46.4	74.2	310	59.8
Greater Accra	3.1	1.2	7.6	390	29.6	24.6	35.1	679	25.9	19.4	33.6	906	32.6	26.7	39.2	490	29.5
Volta	2.5	1.1	5.6	303	43.7	37.3	50.4	474	66.3	60.4	71.8	464	52.5	45.2	59.7	252	50
Eastern	0.3	0	2.2	372	39.2	33.8	44.9	513	49	41.8	56.1	559	48.2	39.7	56.8	264	47.9
Ashanti	1.2	0.5	2.8	661	38.1	33.4	43.1	1060	47.2	39.6	54.9	1043	51.2	44.3	58	705	50
Brong-Ahafo	2.9	1.5	5.6	388	56.9	51.7	61.9	611	60.8	54.7	66.6	524	60.5	49.5	70.4	261	57.6
Northern	7.1	4.2	11.9	488	31.8	26.3	37.9	869	43.2	36.1	50.5	709	61	48.9	71.9	511	53.9
Upper West	2.7	0.8	8.2	108	63.8	56.9	70.1	165	54.5	47.7	61.2	154	60.7	47	72.9	83	58
Upper East	22.1	14.4	32.4	231	41.7	33	50.9	317	37.4	30.8	44.6	238	75.5	63.2	84.7	118	53.4
Wealth Quintile																	
Lowest	6.4	4.4	9.2	918	42.6	38..2	47.2	1427	55.3	50.8	59.6	1306	66.6	60.8	72	728	60.2
Second	2	1.1	3.3	797	40.1	36.2	44.1	1252	59.5	54.9	63.9	1219	59.4	52	66.3	666	57.4
Middle	2.8	1.7	4.6	717	38.4	34.7	42.3	1128	48.1	44.1	52.2	1145	50.9	44.1	57.7	645	48.1
Fourth	2.8	1.5	5.3	625	36.2	32.5	40.1	1110	35.2	30.3	40.4	1108	43.3	36.7	50.2	657	40.5
Highest	5.4	3.3	8.7	537	34	29.7	38.6	874	30.9	25.8	36.5	1024	36.3	30.3	42.7	539	30.9
Age (in months)																	
<12	6.1	4.5	8.3	709	49	45.7	52.3	1156	51.9	48.2	55.6	1173	55.3	49.6	60.8	635	49.2
12-23	5	3.6	6.8	711	44.6	41.1	48.1	1072	47.4	43.1	51.7	1156	54.5	49.7	59.1	655	49.5
24-35	3.3	2.1	5	698	36.4	33.3	39.5	1110	46.7	42.4	50.9	1143	51.4	46.1	56.7	678	48.1
36-47	3.2	2.2	4.7	791	35.8	32.6	39.2	1193	46	42.1	49.9	1149	49.9	44.1	55.8	598	46.7
48-59	2	1.2	3.5	685	29.2	26.3	32.3	1260	41.2	37.3	45.2	1181	49.9	44.5	55.2	667	47.9

Note: n=Weighted number of children (denominator); An insecticide-treated net (ITN) is (1) a factory-treated net that does not require any further treatment (LLIN) or (2) a pretreated net obtained within the past 12 months or (3) a net that has been soaked with insecticide within the past 12 months.

Table 5. Use of Intermittent Preventive Treatment by Pregnant Women by background characteristics, 2003-2016

Background Characteristic	2003 DHS				2008 DHS				2014 DHS				MIS 2016				Percentage Point Change 2003-2016
	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	
Total (National)	0.8	0.4	1.4	1421	43.7	40	47.5	1178	67.5	64.5	70.3	2264	78	73.1	82.3	1285	77.2
Residence																	
Urban	0.7	0.2	2.1	477	46.3	40.2	52.4	455	68.2	63.3	72.7	1009	82.6	77.5	86.7	577	81.9
Rural	0.8	0.4	1.7	944	42.1	37.4	46.8	723	66.9	63.2	70.4	1255	74.3	67	80.5	708	73.5
Region																	
Western	0			128	45.5	34.2	57.3	111	67.3	57.9	75.6	217	77.3	68	84.5	101	77.3
Central	0.8	0.1	5.8	120	45.7	36.6	55.2	123	68.9	63.2	74	258	84.5	77.4	89.6	131	83.7
Greater Accra	1.6	0.4	5.9	150	29.4	20.3	40.4	133	59.3	50.1	68	332	78.7	68.6	86.3	207	77.1
Volta	1.6	0.4	6.4	134	59.8	50	68.8	107	65.1	56.6	72.7	177	75.1	62	84.8	110	73.5
Eastern	0			142	40.8	30.8	51.5	105	64.2	57.3	70.5	206	89.2	80.9	94.2	100	89.2
Ashanti	1	0.2	4.2	245	50.8	40.5	61.1	215	73.2	65.4	79.9	397	79.6	69.4	87.1	238	78.6
Brong-Ahafo	0.3	0	1.8	158	63.7	48.5	76.5	107	80.7	72.1	87.2	214	85	77.3	90.5	111	84.7
Northern	0			208	27.9	20.7	36.3	177	60.7	49	71.3	304	61	48	72.6	211	61
Upper West	1.5	0.4	5.6	49	52.5	42.3	62.6	36	73.8	67.4	79.4	64	82.2	76.1	87	30	80.7
Upper East	2.6	0.7	8.7	86	26	15.7	39.9	63	67.7	58.8	75.5	95	90.8	81.4	95.7	45	88.2
Wealth Quintile																	
Lowest	0.7	0.2	2.5	373	31.2	25.2	37.8	283	64.7	57.4	71.4	519	69.1	58.9	77.7	282	68.4
Second	0.7	0.2	2	319	42.6	35.9	49.5	261	70.8	65.2	75.8	474	74.9	66.8	81.6	269	74.2
Middle	1.1	0.3	3.6	284	50.3	42.6	58	222	64.1	58.8	69.1	433	78.3	71.4	83.9	265	77.2
Fourth	0.4	0.1	2.8	235	49.2	41.5	57	243	63.2	56.5	69.4	444	83.5	76.4	88.8	237	83.1
Highest	1.1	0.3	4.3	210	49.8	40.6	59	169	75.6	68.9	81.2	393	86.6	77.2	92.5	231	85.5
Age (in years)																	
15-19	0			96	44.2	32.7	56.4	80	66.8	55.5	76.4	143	79.3	64.8	88.8	91	79.3
20-24	1.4	0.5	3.8	308	43.9	36.9	51.1	278	61.3	55.4	66.8	441	73.3	64.8	80.4	289	71.9
25-29	1.5	0.7	3.4	384	44.5	38	51.1	342	69.8	64.2	74.8	614	77.1	67.9	84.3	314	75.6
30-34	0			296	46.6	39.5	53.8	223	70.4	65.2	75.2	516	82	74.3	87.8	313	82
35-39	0			225	42.1	33.9	50.7	169	67.4	60.2	73.8	379	82	73.8	88	198	82
40-44	1.3	0.2	8.9	74	38.4	26.7	51.7	68	65.7	56.2	74.1	137	72.5	55.6	84.7	72	71.2
45-49	0			38	21.3	7.3	48.3	17	73.3	58.7	84.1	34	66.2	36.9	86.8	8	66.2

Note: n=Weighted number of women (denominator); IPTp: Intermittent Preventive Treatment during pregnancy is preventive treatment with two or more doses of SP/Fansidar.

Table 6. Percentage of children (6-59 months) with malaria parasites, by background characteristics 2014-2016

Background Characteristic	2014 DHS				MIS 2016				Percentage Point Change 2003-2016
	%	LCI	UCI	n	%	LCI	UCI	n	
Total (National)	26.7	23.8	29.9	2558	20.6	17.4	24.3	2874	-6.1
Residence									
Urban	13.5	10.8	16.9	1175	11.2	8.5	14.6	1276	-2.3
Rural	37.9	33.7	42.4	1384	28.2	22.4	34.9	1598	-9.7
Region									
Western	38.9	30.6	47.9	272	23.5	15.6	33.8	213	-15.4
Central	37.9	27.3	49.8	304	30.2	23.2	38.2	281	-7.7
Greater Accra	11.2	7	17.3	383	4.8	2.8	8.1	406	-6.4
Volta	25.2	14.6	39.8	189	27.5	19.7	36.8	217	2.3
Eastern	29.5	21.8	38.6	237	31.3	21.4	43.2	224	1.8
Ashanti	16.6	11.1	24.2	432	16.6	11.2	23.9	656	0
Brong-Ahafo	26.5	18.8	36.1	259	22.4	12	38	233	-4.1
Northern	40	30.1	50.8	313	25.2	12.2	44.9	464	-14.8
Upper West	37.8	27.5	49.5	66	21.5	13.8	31.9	75	-16.3
Upper East	11.7	8	16.8	105	14.7	10	21	105	3
Wealth Quintile									
Lowest	42.1	36.1	48.5	586	37.2	29.8	45.2	645	-4.9
Second	39.5	34.3	44.9	529	29	21.6	37.7	593	-10.5
Middle	24.6	19.3	30.8	520	17	12.4	22.9	581	-7.6
Fourth	13.9	9.5	19.9	481	12.5	9.2	16.7	588	-1.4
Highest	7.5	4.6	12	443	1.9	0.9	4	466	-5.6
Age (in months)									
6-11 months	18.9	14.2	24.7	260	17	11.8	23.9	310	-1.9
12-23 months	23.3	19.1	28.1	585	17.8	14.2	22.1	648	-5.5
24-35 months	25.4	21.1	30.4	570	19.7	15.1	25.2	670	-5.7
36-47 months	28.9	24.2	34.2	568	21.6	16.8	27.3	591	-7.3
48-59 months	32.9	27.7	38.5	575	25.3	20.6	30.6	655	-7.6
6-23 months	22	18.6	25.7	845	17.6	14.1	21.6	958	-4.4
24-59 months	29.1	25.7	32.8	1713	22.2	18.5	26.4	1916	-6.9

Note: n=Weighted number of children (denominator)

Table 7. Prevalence of Severe Anaemia in Children Aged 6-59 Months in Ghana

Background Characteristic	2003 DHS				2008 DHS				2014 DHS				MIS 2016				Percentage Point Change 2003-2016
	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	%	LCI	UCI	n	
Total (National)	14.3	12.8	15.9	2992	19.1	17	21.4	2342	8.3	7	9.9	2568	6.9	5.4	8.7	2874	-7.4
Residence																	
Urban	9	7.1	11.3	984	13.1	10.4	16.4	894	4.4	3	6.6	1180	4.1	2.2	7.4	1276	-4.9
Rural	16.9	15	18.9	2008	22.8	20	25.9	1448	11.6	9.7	13.9	1388	9.1	7.1	11.7	1598	-7.8
Region																	
Western	15.4	11.1	21.2	293	26.5	19.3	35.3	221	8	5.3	11.8	273	3.9	1.6	9.3	213	-11.5
Central	14.9	10.8	20.2	267	19.2	14	25.7	225	10.7	6.6	17	304	14	8	23.4	281	-0.9
Greater Accra	8	4.7	13.1	324	6	3	11.9	267	4.2	1.4	12.1	389	1.3	0.3	4.6	406	-6.7
Volta	10.2	6.6	15.6	255	16.7	11.5	23.7	203	8.4	5.8	12	189	8.7	5.5	13.5	217	-1.5
Eastern	11.8	8.4	16.4	292	11.2	6.9	17.8	211	5.8	3.3	9.8	238	8.6	5.1	14.1	224	-3.2
Ashanti	14.6	10.8	19.3	553	20.8	14.9	28.2	460	5	2.6	9.5	432	3.7	1	12.9	656	-10.9
Brong-Ahafo	16.8	12.8	21.8	333	19.1	13.6	26.3	250	6.4	3.7	10.8	260	4.4	2	9.4	233	-12.4
Northern	20.1	15.3	26	403	27.8	22.7	33.5	332	18.2	14	23.4	313	12.4	9.1	16.7	464	-7.7
Upper West	11.7	8.1	16.6	86	31.2	24.5	38.8	63	16.5	11.1	23.8	66	9.1	5.9	13.8	75	-2.6
Upper East	15	10.1	21.6	186	15	10.3	21.3	109	6.7	4.1	10.7	105	7.4	4.9	11	105	-7.6
Wealth Quintile																	
Lowest	19.9	17	23	774	26.2	22.5	30.2	585	15.8	12.7	19.6	588	12.1	9.8	14.8	645	-7.8
Second	16.5	13.5	19.9	660	23	19	27.5	543	12.6	9.7	16.2	530	12.1	7.8	18.3	593	-4.4
Middle	13.7	11	17	597	20.4	16.4	25.2	425	7.1	4.5	10.9	523	5	3.2	7.8	581	-8.7
Fourth	11.3	8.3	15.1	521	13.8	10.4	18.2	463	3.2	1.8	5.6	483	2.6	1.5	4.8	588	-8.7
Highest	5.4	3.3	8.6	441	5.7	3.4	9.4	326	0.3	0	1.9	445	0.7	0.2	2.8	466	-4.7
Age (in months)																	
6-11 months	20.8	16.3	26.2	348	28.4	22.7	34.9	245	9.6	6.4	14	260	10	6.2	15.7	310	-10.8
12-23 months	23.1	19.7	26.8	661	24.3	20.5	28.5	521	14	10.6	18.2	587	11.8	9	15.5	648	-11.3
24-35 months	13.6	10.8	16.9	635	23.7	19.4	28.5	492	7.3	5.3	9.9	573	6.3	4.5	8.7	670	-7.3
36-47 months	10.1	8	12.7	716	12.7	9.5	16.8	517	8.5	6	11.9	570	4.5	2.8	7.1	591	-5.6
48-59 months	6.9	5.1	9.2	632	12.2	9.4	15.6	566	2.9	1.8	4.6	578	3.2	1.8	5.9	655	-3.7
6-23 months	22.3	19.5	25.4	1009	25.6	22.2	29.3	767	12.6	9.8	16.1	847	11.3	8.5	14.8	958	-11
24-59 months	10.2	8.8	11.8	1983	15.9	13.7	18.4	1575	6.2	5	7.7	1721	4.7	3.6	6.1	1916	-5.5

Note: n=Weighted number of children (denominator)

Figure 1 Changes in ACCM vs. Malaria Coverage