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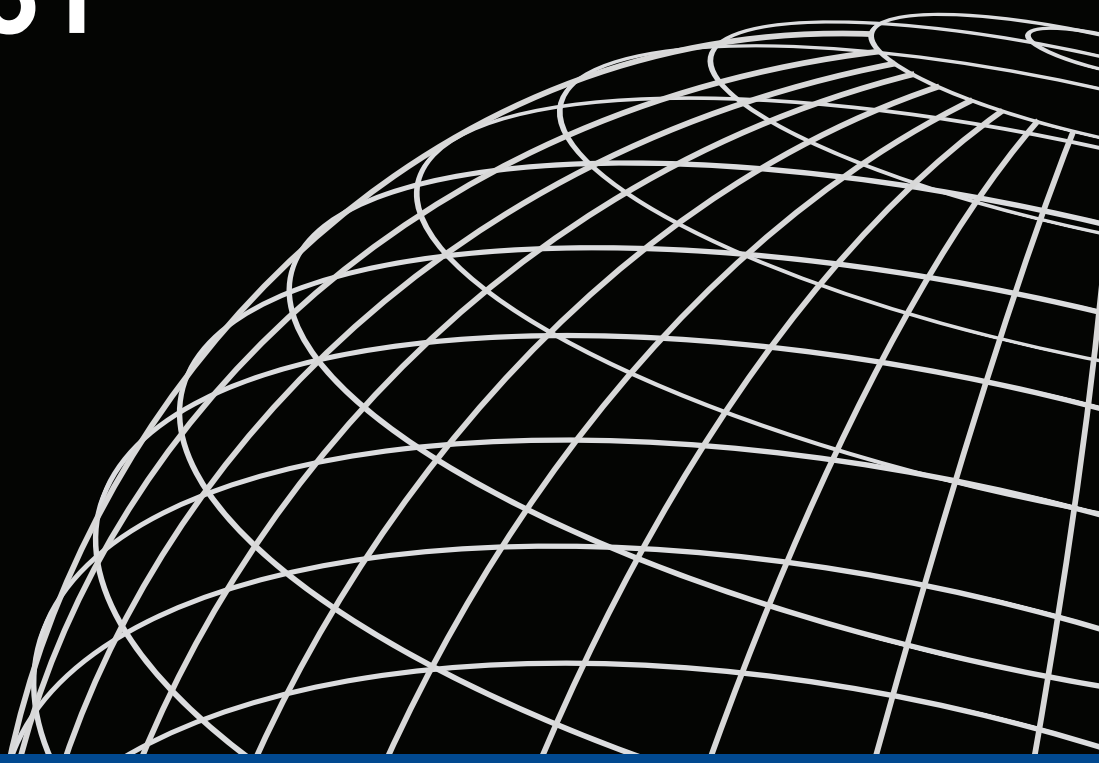
ANEMIA AS AN IMPACT MEASURE OF ITN USE AMONG YOUNG CHILDREN

DHS ANALYTICAL STUDIES 31



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MEASURE DHS assists countries worldwide in the collection and use of data to monitor and evaluate population, health, and nutrition programs. Additional information about the MEASURE DHS project can be obtained by contacting MEASURE DHS, ICF International, 11785 Beltsville Drive, Suite 300, Calverton, MD 20705 (telephone: 301-572-0200; fax: 301-572-0999; e-mail: reports@measuredhs.com; internet: www.measuredhs.com).

The main objectives of the MEASURE DHS project are:

- to provide decision makers in survey countries with information useful for informed policy choices;
- to expand the international population and health database;
- to advance survey methodology; and
- to develop in participating countries the skills and resources necessary to conduct high-quality demographic and health surveys.

DHS Analytical Studies No. 31

Anemia as an Impact Measure of ITN Use among Young Children

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Preface

One of the most significant contributions of the MEASURE DHS program is the creation of an internationally comparable body of data on the demographic and health characteristics of populations in developing countries.

The *DHS Comparative Reports* series examines these data across countries in a comparative framework. The *DHS Analytical Studies* series focuses on analysis of specific topics. The principal objectives of both series are to provide information for policy formulation at the international level and to examine individual country results in an international context.

While *Comparative Reports* are primarily descriptive, *Analytical Studies* comprise in-depth, focused studies on a variety of substantive topics. The studies are based on a variable number of data sets, depending on the topic being examined. A range of methodologies is used in these studies, including multivariate statistical techniques.

The topics covered in *Analytical Studies* are selected by MEASURE DHS staff in conjunction with the U.S. Agency for International Development.

It is anticipated that the *DHS Analytical Studies* will enhance the understanding of analysts and policymakers regarding significant issues in the fields of international population and health.

Sunita Kishor
Project Director

Executive Summary

This report examines the relationship between use of insecticide-treated mosquito nets (ITNs) and moderate-to-severe anemia in last-born children age 6–23 months in malaria-endemic countries in sub-Saharan Africa (between 2001 and 2011). Substantial resources have been invested in malaria control programs in recent years, with clear goals of reducing malaria transmission. Yet malaria-specific outcomes are difficult to measure. An alternative, although not highly specific, is to measure hemoglobin levels and use severe anemia as a proxy for malaria infection. Malaria and anemia are inextricably related. For example, recent research in West Africa has estimated that approximately 15% of anemia in pre-school-age children is attributable to malaria.

Objectives

1) Describe distributions and trends in nationally representative estimates of ITN use and moderate-to-severe anemia over periods of ITN scale-up.

2) Assess the impact of ITN use on prevalence of moderate-to-severe anemia in children age 6-23 months.

Methods

With data from the Demographic Health Surveys (DHS) and Malaria Indicator Surveys (MIS), the study examines associations between ITN use and moderate-to-severe anemia. The analysis uses multivariate logistic regression models with pooled data from multiple countries. Additionally, the study examines the association between change in ITN use and change in anemia over time in countries with relevant data for more than one survey year.

Results

Although ITN use is not associated with odds of moderate-to-severe anemia in most nationally-representative household surveys, when pooled in multi-country analyses, ITN use is associated with lower odds of anemia in last-born children 6–23 months of age. ITN use was significantly associated with moderate-to-severe anemia in countries grouped by low national-level ITN use (<20%), as well as in countries grouped by high national-level ITN use (>20%). In pooled analyses of countries with more than one survey, ITN use increased significantly and prevalence of moderate-to-severe anemia decreased significantly. Increasing ITN use was associated with 19% of the observed reductions in moderate-to-severe anemia, controlling for other covariates. When additional covariates were added to these models, changes in the level of ITN use no longer explained a significant proportion of the observed reduction in anemia; however, changes in the effect of ITN use on anemia between baseline and endline surveys explained 45% of the observed anemia reduction.

Conclusions

Given the evidence that moderate-to-severe anemia is a good measure of impact for malaria control interventions, results of these analyses suggest that the increase in ITN use among young children has had a measurable impact. Results also suggest that, of the variables investigated, ITN use is one of the most important determinants of change in anemia over time. Other important variables include urban-rural residence, history of recent fever, mother's education, and recent meat consumption.

1 Introduction

Substantial resources have been invested in malaria control programs in recent years, with clear goals of reducing malaria transmission. Documenting the impact of these interventions requires measurement of intervention scale-up as well as changes in malaria-associated outcomes. Malaria-specific outcomes are difficult to measure, however. For example, reliable measures of malaria mortality are typically limited to health facilities and small-scale demographic surveillance sites (Sankoh and Byass 2012), and even these are often plagued by measurement error. Parasite prevalence is costly to measure at the population level, and such measures are not sensitive to small-scale changes in malaria transmission risk. An alternative approach, although also not highly specific, is to measure hemoglobin levels and use severe anemia as a proxy for malaria infection.

In a review of randomized controlled trials of malaria control interventions, Korenromp and colleagues found that moderate-to-severe anemia, defined as less than 8 grams of hemoglobin per deciliter of blood, is more sensitive to changes in malaria exposure than is parasite prevalence (Korenromp et al. 2004). Results of this study led Roll Back Malaria (RBM) and the World Health Organization (WHO) to recommend moderate-to-severe anemia as a malaria control indicator (Roll Back Malaria et al. 2009). Mathanga and colleagues found similar results using data from two population-based cross-sectional surveys in Malawi (Mathanga et al. 2010). Decreases in anemia prevalence and parasite prevalence over the three-year study period corresponded with increases in ITN coverage. Senn and colleagues concluded that in Papua, New Guinea, population mean hemoglobin levels and anemia prevalence correlated well with traditional measures of malaria endemicity and could be used for monitoring malaria control strategies (Senn et al. 2010). To date, hemoglobin measurements have been more commonly available in national surveys than parasite prevalence data[1] (58 vs. 24 DHS/MIS in sub-Saharan Africa), and the cost of hemoglobin testing is much lower.

Evaluation of malaria control programs is essential to continued funding and to shaping future health policies. Thus, an examination of severe anemia as a measure of the effectiveness of these programs is vital.

An estimated 3.3 billion people are at risk for malaria (Figure 1). Of the 216 million estimated malaria cases in 2010, 81% were in Africa, as were 91% of the estimated 655,000 malaria deaths (WHO 2011). Consequences of malaria infection include symptoms such as fever, headache, chills, and joint pain, as well as more serious complications such as respiratory distress, renal failure, acute kidney failure, hypoglycemia, seizures, coma, and death. One of the most common symptoms, which can be either mild or severe, is anemia.

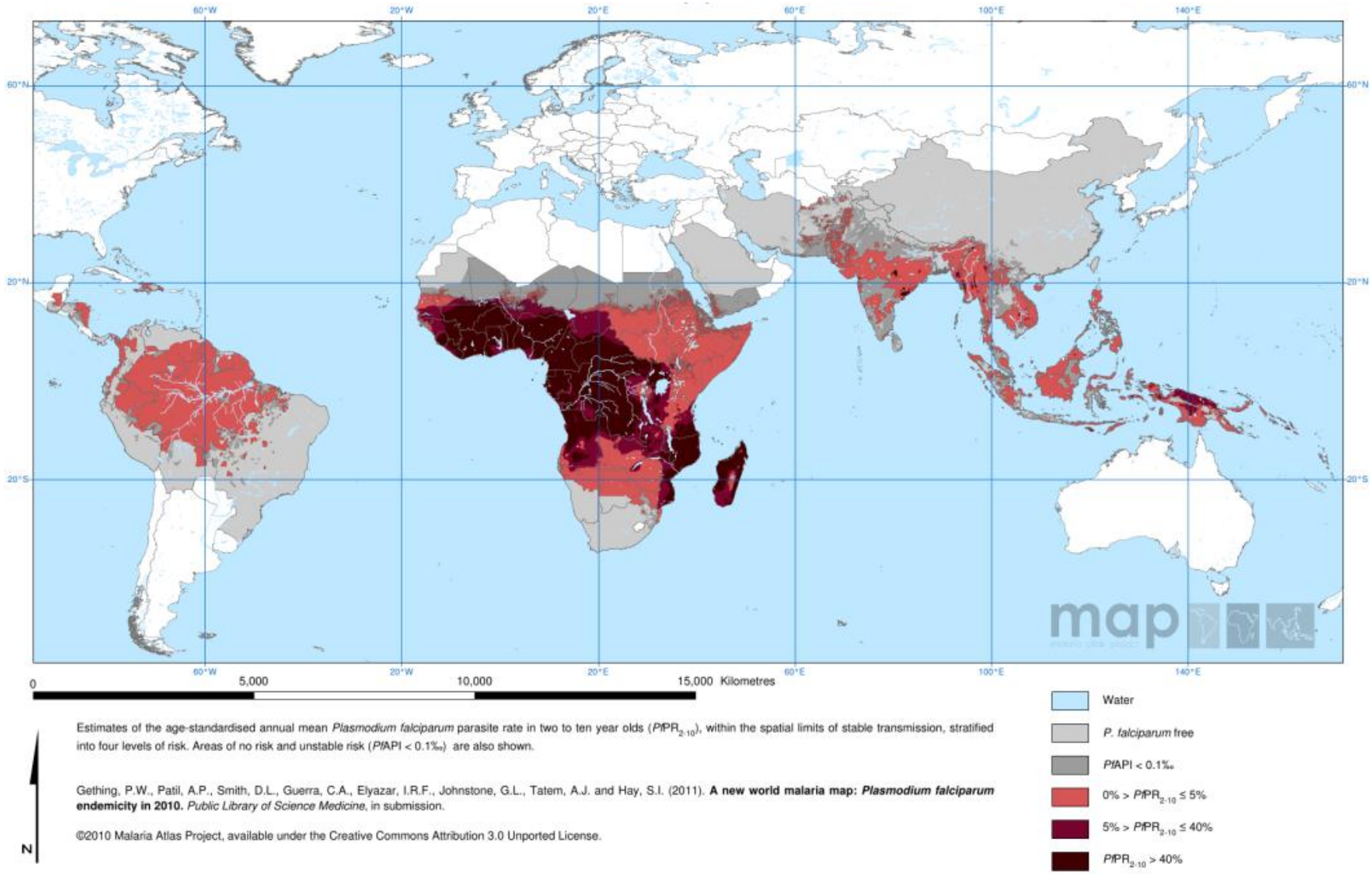
Anemia affects an estimated 25% of the world's population (WHO 2008a), and approximately 68% of preschool-age children under age 5 in sub-Saharan Africa (Figure 2). Some of the health consequences of anemia include impaired cognitive and motor development, impaired growth, impaired immune function, and diminished physical work capacity. Severe anemia is also associated with increased risk of death (CDC 2010). In women, anemia increases the risk of hemorrhaging and sepsis during childbirth, which can lead to premature births or low-birth-weight babies. This leads to infants possibly being born with weakened immune systems, stunted physical development, and learning impairment, and in severe cases can cause their death. Infants who do not receive adequate iron during delivery or via breastfeeding will also be at a higher risk for anemia (UNICEF 6 May 2003) and its associated health consequences.

[1] 58 Malaria Indicator Surveys (MIS) or Demographic and Health Surveys (DHS) with hemoglobin measurements compared with 24 MIS/DHS with parasite prevalence measurements.

Malaria and anemia are inextricably related. Infection with *Plasmodium* spp. leads to sequestration and lysis of red blood cells, as well as to suppressed production of new cells in the bone marrow (dyserythropoiesis). The extent to which *Plasmodium* spp. infections lead to severe anemia is mediated by other individual factors such as immunologic factors (previous exposure to malaria parasites), concurrent infections with other parasites, and nutritional factors, particularly severe iron deficiency. Recent studies have estimated that approximately 15% of anemia in pre-school-age children is attributable to malaria in Burkina Faso, Ghana, and Mali (Soares Magalhães and Clements 2011), and 14% is attributable to malaria in Kenya (Brooker et al. 1999).

Anemia has many etiologies in addition to malaria, and thus is a challenging public health problem to address. Iron deficiency, deficiencies in other nutrients such as folate, vitamin B12, and vitamin A, and diseases such as soil-transmitted helminths (Gulani et al. 2007, Smith and Brooker 2010, Friedman et al. 2005), as well as malaria (Lengeler 2004, Menendez et al. 2000, Meremikwu et al. 2008), are important causes of anemia. Globally, the most significant contributor to the onset of anemia is iron deficiency. It is assumed that 50% of the cases of anemia are due to iron deficiency; however, this can vary by region and population groups (WHO 2008b). Some areas of the world experience a disproportionate burden of anemia due to high prevalence of multiple risk factors. Untangling causal relationships and attributing proportionally representative risks can be difficult in such settings.

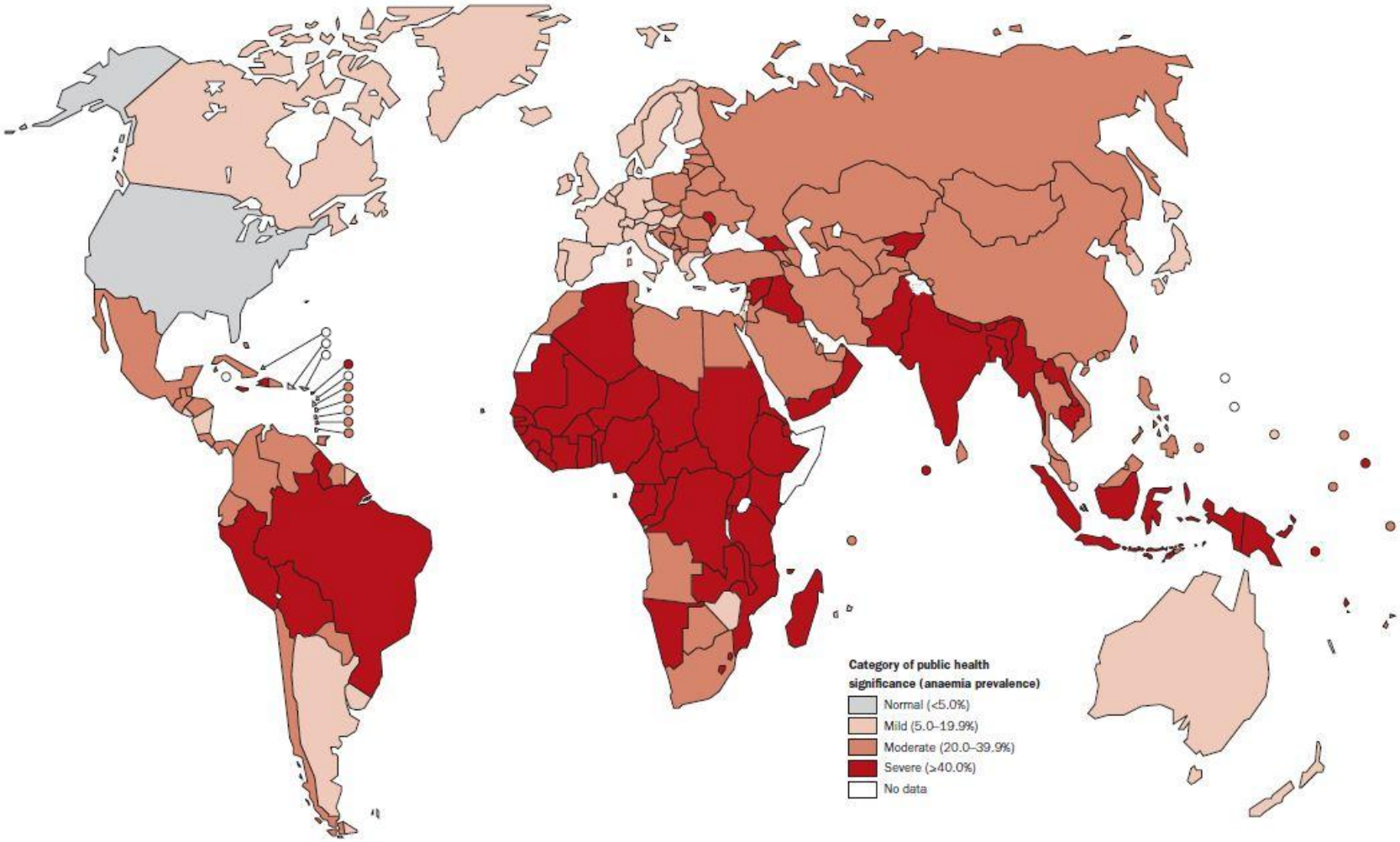
Figure 1. Global map of the spatial distribution *of Plasmodium falciparum* malaria in 2010 stratified by endemicity class (Gething et al. 2011)



Estimates of the age-standardised annual mean *Plasmodium falciparum* parasite rate in two to ten year olds ($PfPR_{2-10}$), within the spatial limits of stable transmission, stratified into four levels of risk. Areas of no risk and unstable risk ($PfAPI < 0.1‰$) are also shown.

Gething, P.W., Patil, A.P., Smith, D.L., Guerra, C.A., Elyazar, I.R.F., Johnstone, G.L., Tatem, A.J. and Hay, S.I. (2011). **A new world malaria map: *Plasmodium falciparum* endemicity in 2010.** *Public Library of Science Medicine*, in submission.

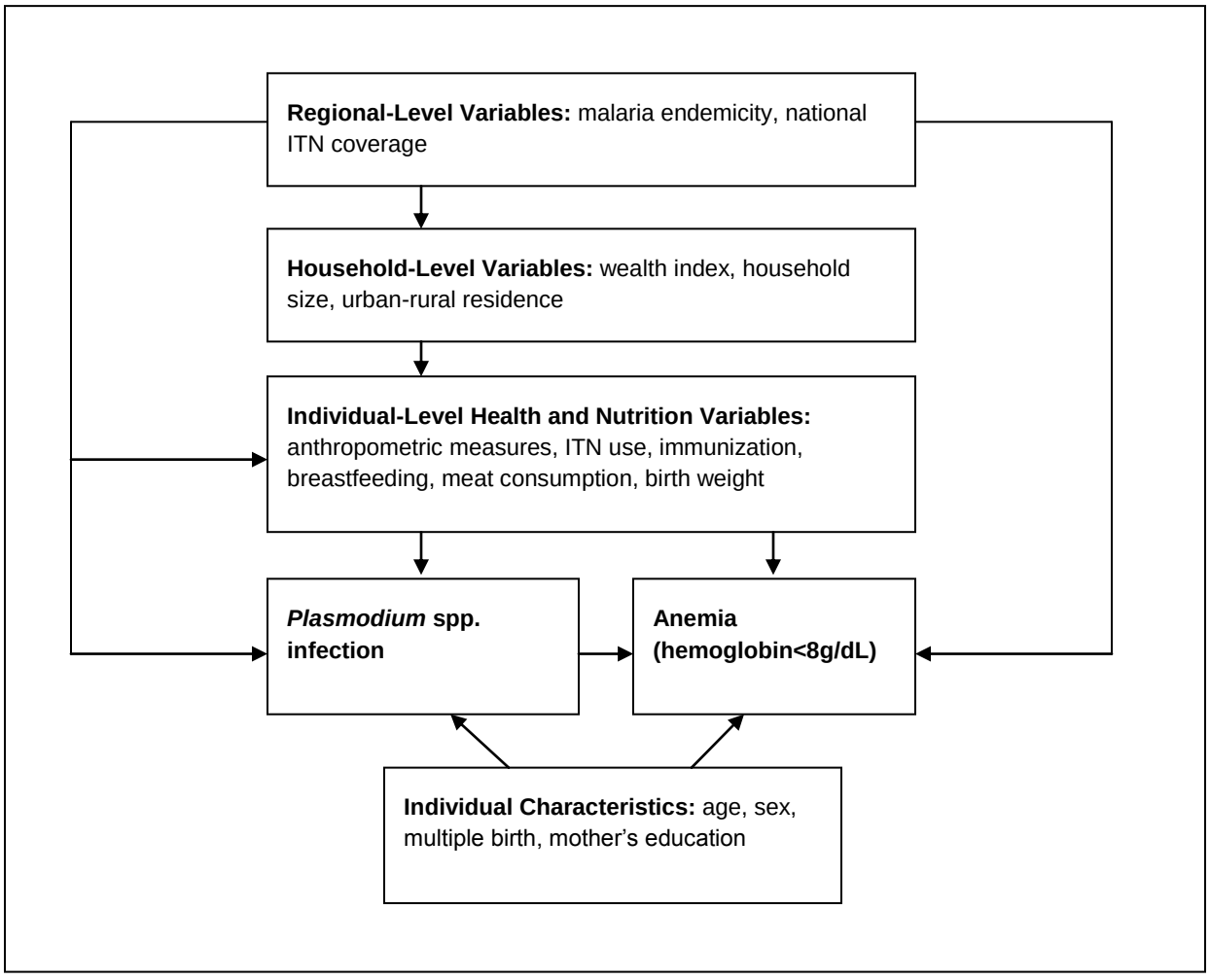
Figure 2. Global map of the spatial distribution of anemia prevalence in pre-school-age children (WHO 2008b)



1.1 Predictors of Anemia

As the conceptual model depicted in Figure 3 indicates, many factors in addition to ITN use are likely to affect a child's risk of anemia. These include macro-level variables such as malaria endemicity, community-level vector control coverage, infrastructure, and a country's level of development. Also included are household-level variables such as household wealth, number of household members, and location of residence, whether urban or rural, as well as housing conditions. Both regional and household-level variables affect anemia risk through more proximate determinants such as an individual's nutrition status, individual-level behaviors such as ITN use, immunization history, feeding practices, and co-morbidities. Similarly, a child's age, sex, birth experience, and certain maternal characteristics influence a child's risk of anemia, as do genetic and immune factors.

Figure 3. A simplified conceptual model of anemia*



* This framework does not include an exhaustive description of predictors of anemia.

1.2 Individual Characteristics

Educational attainment of mothers has been linked to many child health outcomes (Caldwell 1979, Cochrane et al. 1982). Studies specifically focused on anemia in children have found maternal education to be an important predictor, with level of education inversely related to hemoglobin levels. For example, in analysis of data from the National Nutrition Status Survey of Zambia, Wenlock showed parental education to be linked to child death rates as well as to hemoglobin levels of the youngest child in a family (Wenlock 1979). Research in Uganda found maternal education to be inversely associated with hemoglobin levels and anemia (defined as hemoglobin < 11g/dl) (Kikafunda et al. 2009) as well as with stunting (Wamani et al. 2006). In Korea Choi and colleagues found that children age 10 of more educated mothers were significantly less likely to be anemic than were children of less educated mothers (Choi et al. 2011). A multi-country analysis of data from the Demographic and Health Surveys (DHS surveys) found that children with mothers with no formal education were more likely to be anemic than children whose mothers had more than a secondary education (Balarajan et al. 2011). These findings follow the household production theory, which posits that more educated individuals are more likely to acquire and effectively process health information that, in turn, leads to more positive health and nutrition outcomes (Variyam et al. 1999).

The symptoms associated with severe malaria, such as anemia, vary at different ages. For this study, the age range is restricted to children age 6-23 months, since not only are these children at the highest risk of malaria but also the potential impact of malaria control is highest. Due to the passive transfer of maternal immunoglobulins (Riley et al. 2001) and the expression of fetal hemoglobin in neonates and infants (Weatherall et al. 2002), children born in malaria-endemic regions are significantly protected against malaria infection, episodes of clinical malaria, and death from severe malaria in the first 6 months of life (Snow et al. 1998, Riley et al. 2001, Carneiro et al. 2010). After this period, malaria control interventions, such as ITNs, provide the greatest protection for children age 6 months to 3 years in highly endemic areas (Korenromp et al. 2004). The prevalence of anemia (defined as <11 g/dl) has also been shown to decrease with age between 1 and 5 years. In a recent study of children in several countries in West Africa, mean hemoglobin levels were significantly lower in children age 2–5 years than in children age 1–2 (Soares Magalhães and Clements 2011).

Another factor that affects anemia is a child's sex. Males and females have different physiological needs for iron stores and thus different thresholds for hemoglobin levels that are considered normal. Different thresholds are used for women during pregnancy as well, because the need for iron increases during this period. Heavy blood loss due to menstruation can also affect hemoglobin concentrations, leading to iron deficiency anemia. In young children not subject to menstruation or pregnancy, sex effects might not be expected; however, research has shown evidence of enhanced resistance to severe malaria (Guindo et al. 2007) and malarial anemia (Orimadegun and Sodeinde 2011) in males due to sex-linked genetic mutations such as G6PD deficiency. Despite this genetic advantage, several other studies in Ghana (Ronald et al. 2006) and Kenya (Halliday et al. 2012) have found that young boys had higher risk of anemia than young girls.

1.3 Individual-Level Health and Nutrition

A child's risk of anemia is also influenced by birth experiences. Mother's nutrition affects fetal growth and stores of micronutrients that she will share with her baby in utero and pass on in breast milk after birth (Steketee 2003). Being a twin or multiple birth increases the risk of maternal anemia and low birth weight, both of which increase the risk of anemia in the child (Crawley 2004). Low birth weight is also an outcome of maternal malaria. Children born to mothers with malaria during pregnancy have twice the risk of low birth weight compared with children born to uninfected mothers (Guyatt and Snow 2004). Low birth weight and preterm birth lead to iron-deficiency anemia, as children have reduced iron stores at birth (Balarajan et al. 2011). Low birth weight is the most significant risk factor for neonatal death in sub-Saharan Africa, with a population attributable risk of approximately 19% (Guyatt and Snow 2004). Thus multiple birth status, low birth weight and other maternal factors play a role in determining a child's risk of anemia.

Nutritional factors are also key determinants of anemia risk. After the age of 6 months, most children have a need for iron for growth and development that surpasses the iron supplied by breast milk (Ziegler et al. 2011). In addition, many complementary foods that are introduced to infants are low in iron. Several studies have documented links between duration of breastfeeding and iron deficiency anemia in different countries (Innis et al. 1997, Kim et al. 1996, Arvas et al. 2000, Meinzen-Derr et al. 2006, Monterrosa et al. 2008, Chantry et al. 2007). Foods high in iron that can affect iron deficiency anemia include animal-based products such as meat and eggs. A study in Nigeria found that weekly meat intake was one of the factors significantly associated with hematocrit levels (Gara et al. 2010). Other nutritional factors that influence risk of anemia include consumption of micronutrients that affect erythrocyte synthesis and/or development such as folic acid, vitamin B12 and vitamin A (Balarajan et al. 2011). Aside from anemia, another common way to measure undernutrition is through use of the anthropometric measures of height-for-age, weight-for-age, and height-for-weight. Several studies have found a significant association between stunting and anemia (Friedman et al. 2005, Ngnie-Teta et al. 2007b) and other measures of anthropometric failure and anemia (Soares Magalhães and Clements 2011, Ehrhardt et al. 2006).

A child's risk of anemia is influenced by infection status. In addition to malaria, other infections can cause anemia. Diarrheal illness can lead to a diminished capacity for iron and nutrient absorption as well as direct loss of iron. Research has shown positive associations between diarrhea and anemia (Ngnie-Teta et al. 2007b). Similarly, fever and anemia have been shown to be positively associated (Mathanga et al. 2010), which is to be expected because malaria can cause both outcomes. Fever is not a specific measure of malaria infection, however, and could be an indication of other infections that can also lead to anemia (such as bacteremia). Some anemia-causing infections are preventable with timely and effective immunization. A study in Benin and Mali of risk factors for anemia found that incomplete immunization was strongly associated with a high prevalence of moderate-to-severe anemia (Ngnie-Teta et al. 2007b).

As previously mentioned, use of ITNs affects risk of malaria infection and through this mechanism, affects risk of anemia. The protective effect of ITNs for anemia has been well documented (Korenromp et al. 2004, Mathanga et al. 2010, Ngnie-Teta et al. 2007b, Ter Kuile et al. 2003, Fraser-Hurt et al. 1999, Abdulla et al. 2005, Sangha and Johnson 2009, Soares Magalhães and Clements 2011, Holtz et al. 2002). Examples include nationally representative survey data such as Benin DHS 2001 and Benin DHS 2006, which showed that in households in which all children under age 5 used mosquito nets the odds of anemia were 0.44 compared with odds of 0.59 among children in other households (Sangha and Johnson 2009). Examples also include randomized control trials, as in western Kenya, where ITNs reduced incidence of moderate-to-severe anemia by 60% (Ter Kuile et al. 2003). It is important to note that ITN ownership is sometimes collinear with socioeconomic status, especially in settings in which mass ITN distribution campaigns have not been implemented (Soares Magalhães and Clements 2011).

1.4 Household-Level Factors

Socioeconomic status is a well-recognized predictor of health status for many health outcomes, including anemia. People with few resources, particularly with little household wealth, are more susceptible to anemia and its consequences (Mathanga et al. 2010, Ngnie-Teta et al. 2007b, Balarajan et al. 2011, Magalhães and Clements 2011, Raso et al. 2006). A multi-country analysis of DHS data showed that children living in households in the lowest wealth quintile had a 21% higher risk of anemia compared with children living in households in the highest wealth quintile (Balarajan et al. 2011). Similar patterns have been seen in individual country analyses.

Location of households, whether urban or rural, also influences the risk of anemia. Residents of rural households often are more likely to be exposed to malaria and other anemia-causing parasites. In addition, foods high in iron can be more difficult to obtain and preserve in rural settings, especially where electricity is unavailable. Rural residence often correlates with lower wealth status. Thus, determining the effect of household location versus household wealth can be challenging. In a multi-country pooled analysis of risk factors for anemia in children, household residence was not significantly associated with anemia, controlling for wealth quintile and other demographic and socioeconomic factors (RR = 1.00 (0.99-1.01)) (Balarajan et al. 2011). A study in Benin and Mali of risk factors for anemia found that rural residence was a significant predictor of risk of anemia in Mali (Ngnie-Teta et al. 2007b). In another study of anemia in four west African countries, rural residents had significantly increased risk of anemia compared with urban residents (Soares Magalhães and Clements 2011).

1.5 Regional-Level Factors

Risk of malarial anemia is largely determined by environmental factors such as elevation, temperature, and rainfall patterns, as these factors determine vector abundance and longevity as well as the rate of parasite development. These environmental factors can be combined to form a suitability index that determines overall risk of malaria transmission. Malaria researchers use several different measures of suitability. The Malaria Atlas Project (MAP) has classified maps based on *P. falciparum* prevalence rate in children age 2 to 10. These maps can be used to classify regions into no-, low-, medium-, or high-risk areas.

Another regional-level factor to consider in studies of anemia is ITN coverage. There is some evidence that individuals living in communities with high levels of ITN coverage receive protection regardless of personal use of ITNs due to reduced mosquito populations (Hawley et al. 2003, Howard et al. 2000).

1.6 Unexplored Covariates

Several other important causes of anemia were not included in our analyses due to lack of data. These include genetic causes such as α-thalassemia and sick cell disease (Modell and Darlison 2008), infection with HIV in pregnancy (Volberding et al. 2004), and other co-infections such as schistosomiasis, hookworm, and bacteremia (Gulani et al. 2007, Friedman et al. 2005, Smith and Brooker 2010, Williams et al. 2009, Brooker et al. 1999, Stoltzfus et al. 2000). The population attributable fraction (PAF) of anemia due to these other infections is low due to the relative low prevalence of the infections compared with malaria and iron deficiency. Season of data collection, and corresponding climate patterns were also beyond the scope of our analyses. Future research should attempt to control for these factors, which could bias results (Korenromp et al. 2004).

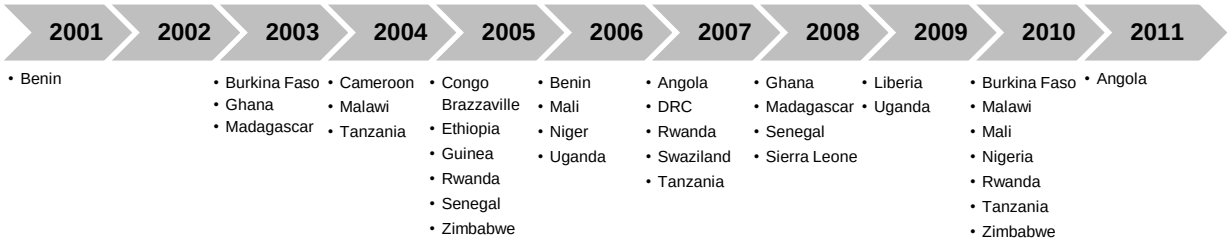
Figure 4. Map of countries with surveys conducted between 2001 and 2011, containing both ITN use and hemoglobin data for children 6–23 months of age

2 Methods

2.1 Data Sources

Data included in our analysis come from Demographic and Health Surveys (DHS) and Malaria Indicator Surveys (MIS) conducted in malaria-endemic countries in sub-Saharan Africa that collected data on both ITN use and on hemoglobin levels in children age 6 to 23 months. As ITNs were not widely available in most countries before 2000, most DHS surveys did not ask about mosquito net use prior to this time. Also, hemoglobin data were not collected in many surveys before 2000. Thus, the analyses focus on the period from 2001 to 2011. Only surveys for which datasets were publicly available before April 2012 were used, resulting in 35 surveys (Figures 4–6; Appendix Table A). Data are nationally representative responses to household and individual questionnaires asked of women of reproductive age 15–49. Responses to child health and nutrition questions and anthropometric measurements were collected for all children born to interviewed women during the five years immediately preceding the survey. Hemoglobin levels were only measured for children age 6–59 months.

Figure 5. Timeline of available survey data



2.2 Study Population

Last-born children age 6–23 months of interviewed women of reproductive age 15-49, born in the five years immediately preceding the survey, comprised the study population. Children under age 6 months were excluded because hemoglobin concentrations in infants are confounded by maternal anemia status. The age range of 6–23 months was selected because high levels of anemia occur in this age group (Kikafunda et al. 2009, Zlotkin 2003, Eliades et al. 2006). Other practical reasons for restricting the study sample to children of this age range include the relevant denominators of the other variables of interest in the regression models; breastfeeding is recommended by WHO up to age 24 months (WHO 2001) and immunization coverage is typically assessed in children age 12-23 months. Restriction to last-born children was done to eliminate non-independent outcomes resulting from intra-household clustering.

2.3 Study Variables

2.3.1 Outcome: Moderate-to-Severe Anemia

Moderate-to-severe anemia was defined as blood hemoglobin levels less than 8 g/dl as measured in capillary blood from a finger or heel stick. Hemoglobin levels were measured using a HemoCue portable spectrophotometer. This cut-off is used to define anemia for studies of impact of malaria control interventions (Korenromp et al. 2004).

2.3.2 Explanatory Variables

For the purpose of this analysis, variables found in the literature to be related to anemia were reviewed and included wherever possible, based on data availability (Table 1). Wealth was measured by means of an asset-based score defined via principal components analysis (Rutstein and Johnson 2004). Each survey has its own score that is not comparable across countries or over time. It is a cross-sectional measure of relative wealth. Residence was defined as whether a household was located in a rural or urban area. The mother's educational level was defined as a categorical variable with three categories: no education; having attended primary school whether or not primary school was completed; or having attended some or all of secondary school or higher. Mother's age was also considered. The referent category was age 18-34, which was compared with age 17 and younger, and to age 35 and older. The child's age was also included as a categorical variable with 6-11 months as the referent group, compared with 12-17 months and 18-23 months. Child's sex (male or female) was included in models. Whether or not the child was born as a single or multiple birth was included, as was history of recent fever within the two weeks immediately preceding the interview, based on mother's reporting.

Additional covariates were available only from a subset of surveys in which detailed child health and birth history data were collected; the MIS surveys often do not include extensive child health modules. Variables include anthropometric measures of height-for-age, weight-for-age and weight-for-height, immunization history, recent meat consumption, and whether or not the child was born with low birth weight. To avoid multi-collinearity, only one anthropometric measure was included in models. Low height-for-age (stunting) was defined as a value less than two standard deviations below the mean height-for-age of the WHO reference population (WHO 2006). Complete immunization was measured by whether or not the child had received the full array of recommended vaccines, including one dose of measles vaccine, three or more doses of diphtheria, pertussis, and tetanus (DPT) vaccine, three or more doses of polio vaccine, and the Bacille Calmette-Guérin (BCG) vaccine against tuberculosis.

Recent meat consumption was determined by responses to the food history section of questionnaires, which asked mothers about the food items their children had consumed the previous day and the previous night. Response options varied among countries but were classified as meat if they included liver, kidney, heart, or other organ meats; any meat such as beef, pork, lamb, goat, chicken, duck, rabbit, or rodents; and fish, shellfish, and other seafood. As children age 6 months and older are recommended to consume complimentary foods in addition to breast milk and to continue breastfeeding until age 2 (WHO 2003), for the sake of this analysis breastfeeding was classified by whether or not a child was partially breastfed (breastfed but consuming complimentary foods as well). Finally, low birth weight was defined as a child born at less than 2500 grams, measured by a health card or by mother's recall.

Table 1. Summary of explanatory variables

Variable	Type	Details of measurement
Wealth Index	Categorical with 5 ordinal categories	Asset-based principal component analysis
Residence	Categorical with 2 categories	Household classified as being in an urban or rural setting
Mother's Education	Categorical with 3 categories: none, primary, or secondary or greater	Based on response to woman's questionnaire on number of years of schooling completed.
Child's Age	Categorical with 3 categories: 6-11 months; 12-17 months, and 18-23 months	Based on date of birth and date of interview
Child's Sex	Categorical with 2 categories: male, female	From women's interview
Multiple Birth	Categorical with 2 categories: singleton birth or multiple birth	From women's interview
Recent Fever	Categorical with 2 categories: yes/no	Whether or not the child had a fever in the 2 weeks preceding interview by mother's report.
Stunting	Categorical with 2 categories: yes/no	Height for age more than 2 standard deviations below the mean value for the WHO referent population.
Complete Immunization	Categorical with 2 categories: yes/no	Whether or not child had completed full set of recommended immunizations: measles, ≥ 3 doses of DPT, ≥ 3 doses of polio and BCG.
Recent Meat Consumption	Categorical with 2 categories: yes/no	Based on mother's response about food consumed by child in past 24 hours. Includes liver, kidney heart or other organ meats; any meat such as beef, pork, lamb, goat, chicken, duck, rabbit or rodents; fish, shellfish, and other seafood.
Breastfeeding	Categorical with 2 categories: yes/no	Whether or not a child was partially breastfed (breastfed but consuming complimentary foods as well).
Low Birth Weight	Categorical with 2 categories: yes/no	Birth weight less than 2500 grams as reported on health card or by mother's report.

2.4 Analytical Procedures

Figure 6 summarizes the analyses used in this report. Descriptive analyses were conducted on all available survey data to examine distributions of moderate-to-severe anemia and of ITN use in last-born children age 6–23 months, as well as ecologic associations between the two. A scatterplot of national ITN use against national moderate-to-severe anemia prevalence was made; the exponentiated slope of the best-fit line from this graph was used to estimate the odds of anemia in ITN users compared with the odds of anemia in non-users.

A subset of these survey data was used for multivariable logistic regression analyses with the aim of examining associations between ITN use and moderate-to-severe anemia in last-born children age 6–23 months (Section 1). Analyses were limited to one survey per country in order to eliminate potential bias from correlated data. The most recent survey from each country was used for these regression models (22 in total). Covariates examined included household-level variables such as wealth and residence, individual-level health and nutritional variables (anthropometric measures, immunization, breastfeeding), and individual-level characteristics (age, sex, and mother's education). The association between ITN use and anemia was first examined for each country for each survey year independently and then in a pooled multi-country model weighted to adjust for the mid-year population in each country at the time of survey. Tests for heterogeneity (I2 tests) were run to evaluate whether or not random effects models were necessary (Ades et al. 2005, Higgins et al. 2003)

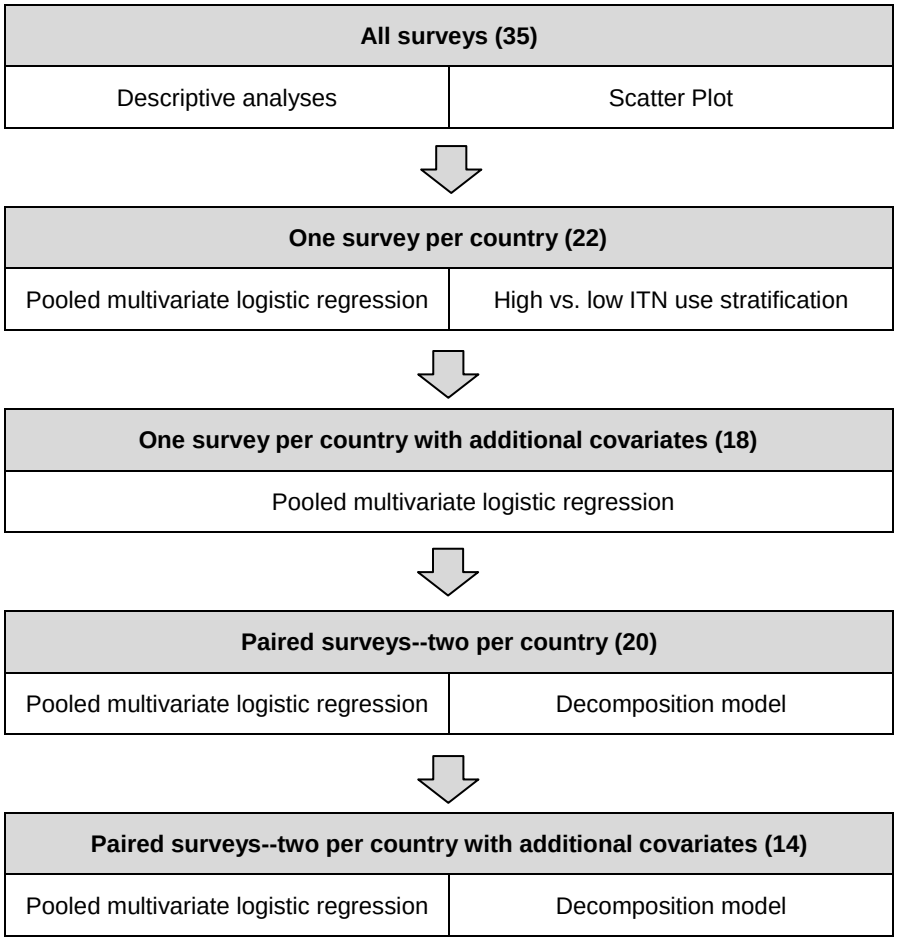
Additional logistic regression analyses were performed for surveys containing covariates only included in a subset of survey dataset, such as immunization status, meat consumption, breastfeeding history, etc. (18 in total). The same strategy of running individual and pooled models, described previously, was used. The objective was to explore the importance of these additional covariates in modeling moderate-to-severe anemia in young children.

Due to the large number of surveys in which ITN use was low, a stratified analysis was conducted separating countries with low ITN use (<20%) and those with high ITN use (20% and higher). This cut-off was chosen in order to have sufficient power to conduct stratified pooled analyses. Thirteen surveys had high ITN use and nine had low ITN use by this definition.

The next set of analyses (Section 2) was conducted to look at the impact of increased ITN coverage on the prevalence of moderate-to-severe anemia in countries over time. Data were used for countries in which more than one survey containing both ITN use questions and hemoglobin measurement was conducted (10 pairs; 20 surveys). As not all of these surveys contained all of the covariates of interest, a subset of paired surveys were used for additional analyses (7 pairs; 14 surveys). Several techniques were employed. First, a multivariable logistic regression model was fitted on pooled data in which the first of the two surveys from each country was labeled baseline and the second, endline. The baseline variable was added as a predictor to the model of moderate-to-severe anemia and an interaction term was added to assess whether or not there were differential effects of ITN use on anemia between baseline and endline surveys. Second, multivariate Blinder-Oaxaca decomposition models for nonlinear response data were run (Powers and Pullum 2006, Powers et al. 2011). These models were employed to estimate the composition and effect of ITN use and other variables on change in anemia between baseline and endline surveys. Similar methods have been used by other researchers to estimate the relative importance of various predictors to child survival in Rwanda and in Benin (Rutsetin et al. 2009, Hong et al. 2009).

Methods in which multilevel models that include national-level, household-level, and individual-level variables are used to examine the effect of baseline anemia prevalence were considered. A previous study of risk factors for anemia that used multilevel modeling did not find a significant difference in strengths of association between risk factors and anemia between multilevel models and single-level multivariate models (Ngnie-Teta et al. 2007a, Higgins et al. 2003). As a result, analyses were restricted to single-level models.

Figure 6. Summary schematic of analyses conducted*



* Numbers in parentheses represent total numbers of surveys included in each subset of analyses.

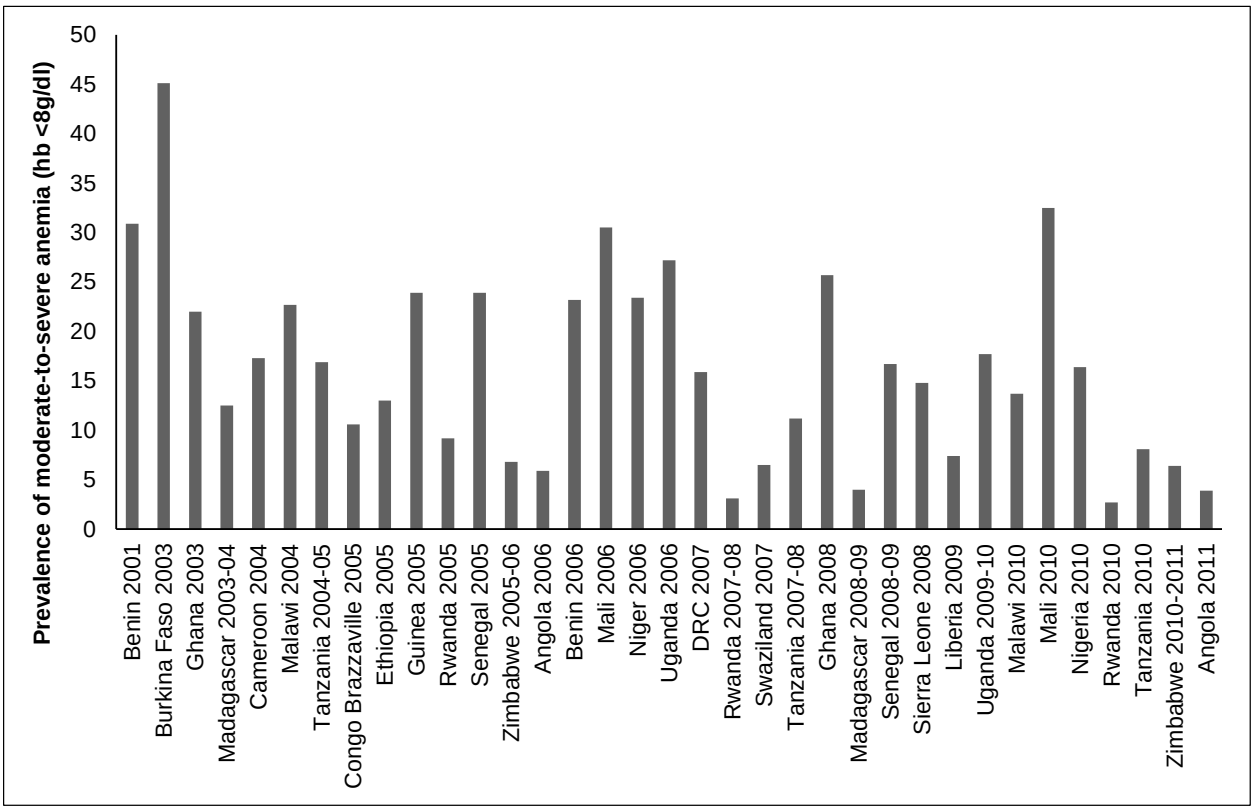
3 Results

3.1 Section 1: Association between ITN Use and Moderate-to-Severe Anemia

3.1.1 Descriptive Analyses

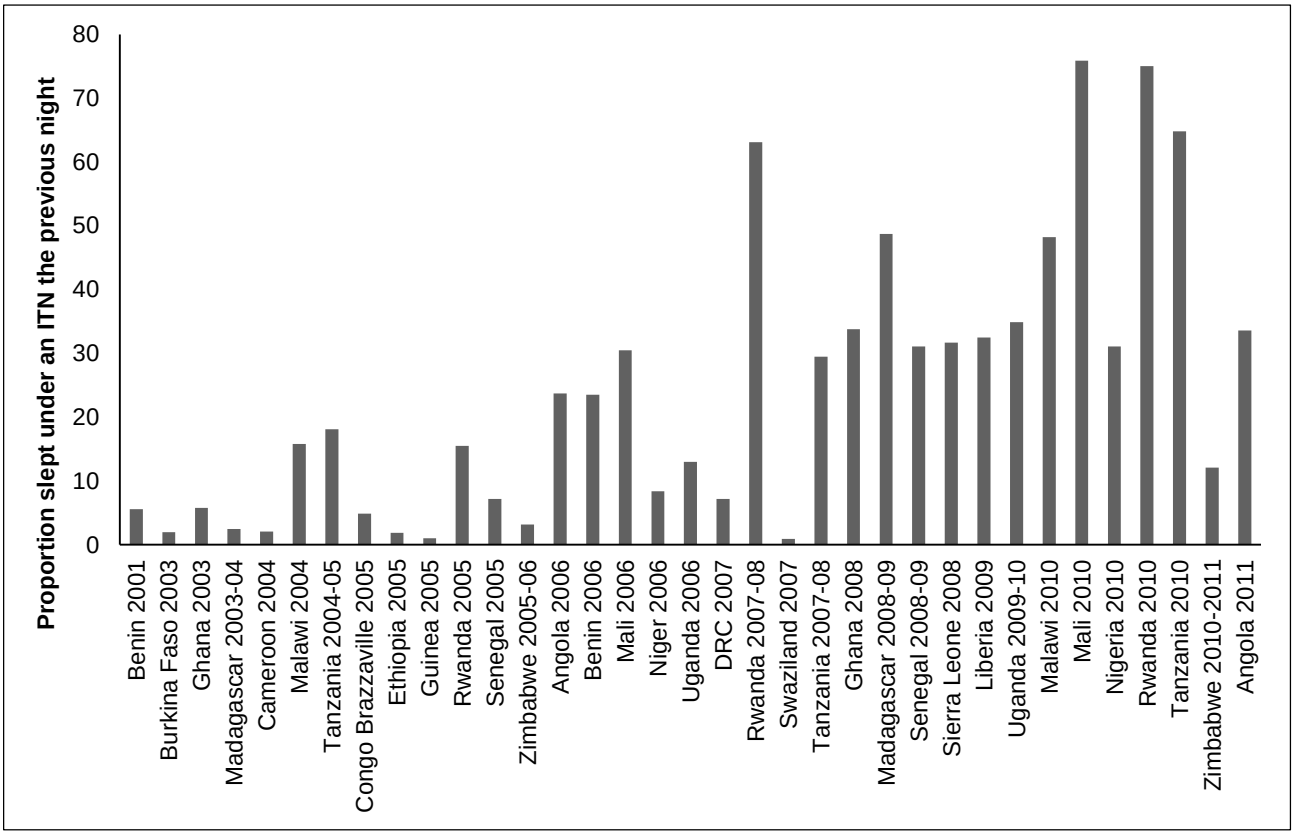
In surveys conducted in malarious countries in sub-Saharan Africa between 2001 and 2011, prevalence of moderate-to-severe anemia in last-born children age 6-23 months ranged from 3% in Rwanda in 2010 to 45% in Burkina Faso in 2003 (Figure 7; Appendix Table B).

Figure 7. Prevalence of moderate-to-severe anemia in last-born children age 6-23 months



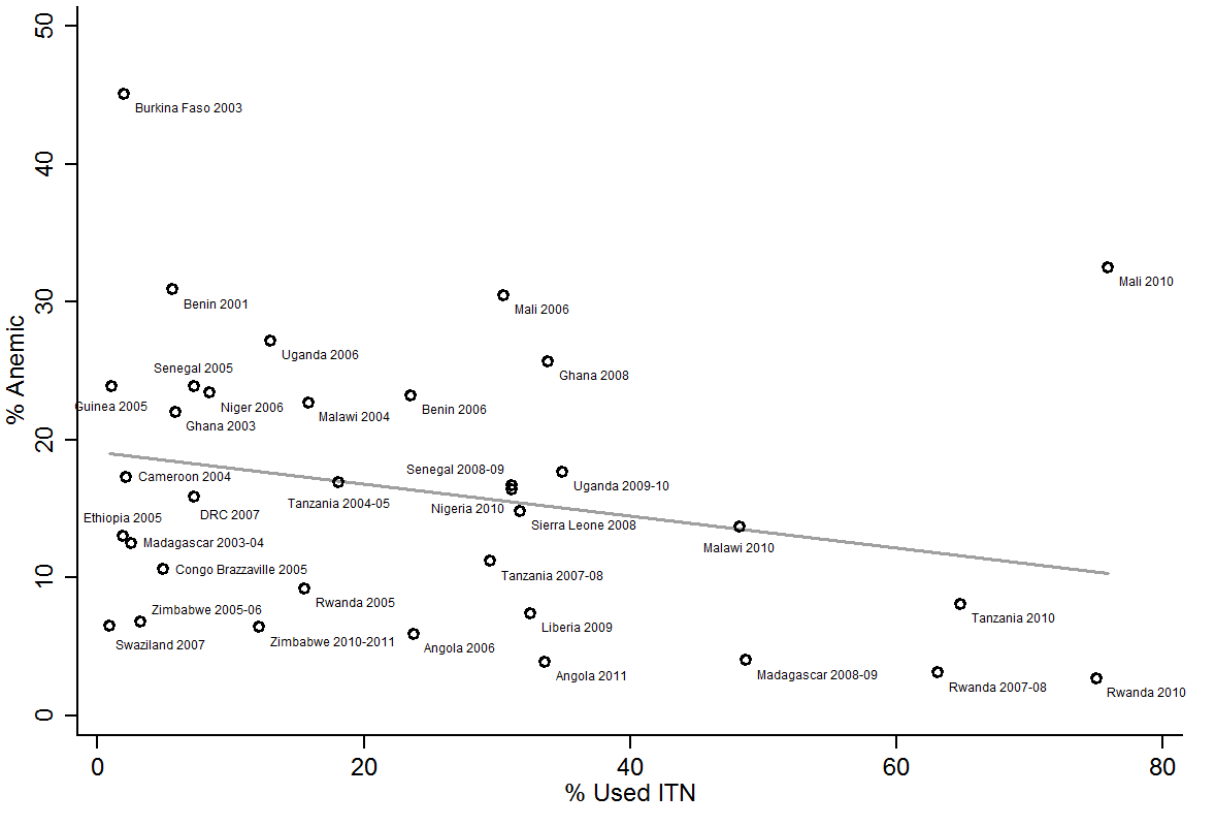
The proportion of last-born children age 6-23 months who used an ITN the night preceding the survey ranged from 1% in Swaziland in 2010 to 76% in Mali in 2010 (Figure 8; Appendix Table C).

Figure 8. The proportion of last-born children age 6–23 months using ITNs the night before the survey



A scatterplot of ITN use and moderate-to-severe anemia in last-born children age 6-23 months shows an inverse relationship between the proportion of children using ITNs and the prevalence of anemia at the national level (Figure 9). Each dot on this graph represents a survey (country, year). The best fit line has a slope of -0.1155; thus, for every 10% increase in use of ITNs among these children, the prevalence of anemia decreases by approximately 1%. Exponentiating the slope of the best-fit line produces an estimate of the odds of moderate-to-severe anemia per 1% increase in ITN use. As illustrated, the odds of anemia decrease with increasing ITN use (OR = 0.89). There are a few evident outliers, including Mali 2010 and Burkina Faso 2003, both of which have high anemia prevalence. For comparative purposes, a model of the pooled effect of ITN use on moderate-to-severe anemia, adjusted only for dataset as a dummy variable, produces an odds ratio of 0.87 (0.72–1.06).

Figure 9. Correlation between ITN use and moderate-to-severe anemia in last-born children age 6-23 months



n = 35

Note: OR based on exponentiated slope of line = 0.8909. R^2 =6.4%

3.1.2 Multivariable Analyses

Table 2 presents results of unadjusted and adjusted logistic regression models of moderate-to-severe anemia in last-born children age 6-23 months, showing a range of associations between ITN use and anemia by survey. In unadjusted models, significant protective effects of ITNs were seen in Benin 2001, Benin 2006, Cameroon 2004, DRC 2007, Ethiopia 2005, and Tanzania 2004-05 (odds ratios and 95% CI are below 1.0). Assocations were marginally significant in Malawi 2010 and Niger 2006. A marginally significant inverse assocation was seen in Madagascar 2008-09, in which ITN use was associated with increased odds of anemia. Although the Swaziland 2007 survey measured both hemoglobin levels and ITN use in the target population, ITN use was very low and perfectly predicted anemia; thus it was not possible to calculated an odds ratio for this association. Estimated odds ratios for the Madagascar 2003-04 survey and for the Burkina Faso 2003 survey had large uncertainty around the estimates, likely due to a combination of small sample size and low reported ITN use.

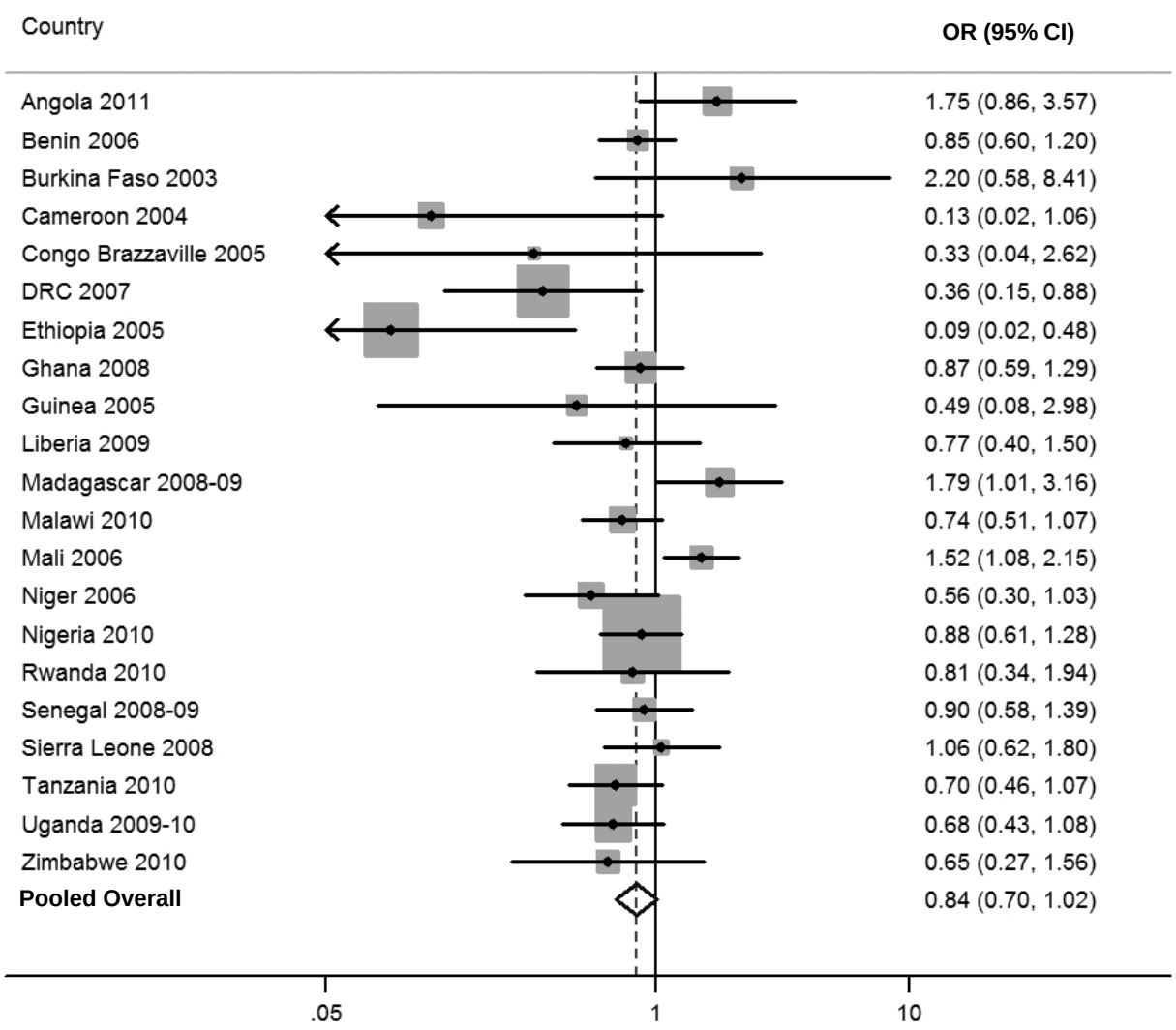
Table 2 and Figure 10 also present results of adjusted models in which adjusted odds ratios of moderate-to-severe anemia in last-born children age 6-23 months who used ITNs are compared with those who did not use ITNs. Odds ratios and 95% confidence intervals are shown for each survey, as well as for a model in which all survey data are pooled (the most recent survey from each country, 22 in total). All models are adjusted for urban-rural residence, wealth quintile, multiple birth status (child is a single birth, twin, or more), mother's educational level (no education, primary, secondary or higher), child's sex, child's age (6-11 months, 12-17 months, 18-23 months), and history of recent fever (within the past two weeks). The pooled model is also adjusted for a dummy variable for the survey. Significant protective effects of ITN use were seen only in DRC 2007 and Ethiopia 2005. In Cameroon 2004 and Niger 2006, the protective effects of ITN use were marginally significant ($p<0.1$). ITN use was associated with higher odds of anemia in Madagascar 2008-09 and in Mali 2006, and marginally so in Senegal 2005. In a multi-country pooled model, ITN use was shown to be marginally significantly associated with reduced odds of moderate-to-severe anemia (OR = 0.79; 95%CI = 0.66-0.96). Significant protective effects of ITNs were seen in Ethiopia 2005 and DRC 2007. Significant negative associations between ITN use and anemia were seen in Madagascar 2008-09 and in Mali 2006. The pooled model revealed a protective effect of ITN use on odds of moderate-to-severe anemia (OR = 0.84; 95%CI = 0.70-1.02).

Table 2. Unadjusted and adjusted associations between ITN use the night before the survey and moderate-to-severe anemia in last-born children age 6-23 months (odds ratios)

	Unadjusted				Adjusted*				
	OR	LCI	UCI	p-value	OR	LCI	UCI	p-value	N
Angola 2006	0.55	0.12	2.50	0.435	0.94	0.17	5.33	0.945	257
Angola 2011	1.66	0.83	3.33	0.152	1.75	0.86	3.59	0.124	1,040
Benin 2001	0.26	0.09	0.78	0.017	0.40	0.12	1.31	0.129	736
Benin 2006	0.68	0.48	0.95	0.024	0.85	0.60	1.21	0.372	1,387
Burkina Faso 2003	1.54	0.39	6.01	0.536	2.20	0.57	8.44	0.250	941
Cameroon 2004	0.10	0.01	0.80	0.029	0.13	0.02	1.08	0.059	1,083
Congo Brazzaville 2005	0.24	0.03	1.82	0.167	0.33	0.04	2.63	0.294	636
DRC 2007	0.31	0.13	0.74	0.009	0.36	0.14	0.89	0.027	1,042
Ethiopia 2005	0.08	0.02	0.42	0.003	0.09	0.02	0.48	0.005	1,225
Ghana 2003	1.30	0.71	2.38	0.391	1.34	0.69	2.62	0.384	968
Ghana 2008	0.79	0.54	1.16	0.227	0.87	0.59	1.29	0.492	717
Guinea 2005	0.42	0.08	2.13	0.297	0.49	0.08	2.98	0.435	803
Liberia 2009	0.78	0.40	1.50	0.448	0.77	0.39	1.51	0.445	1,129
Madagascar 2003-04	1.23	0.29	5.30	0.776	--	--	--	--	613
Madagascar 2008-09	1.74	0.99	3.04	0.053	1.79	1.01	3.17	0.046	1,565
Malawi 2004	0.65	0.38	1.11	0.114	0.79	0.47	1.33	0.377	759
Malawi 2010	0.69	0.47	1.00	0.051	0.74	0.51	1.07	0.111	1,490
Mali 2006	1.24	0.88	1.74	0.210	1.52	1.07	2.14	0.019	1,169
Mali 2010	1.29	0.82	2.04	0.273	--	--	--	--	548
Niger 2006	0.55	0.30	1.01	0.052	0.56	0.30	1.04	0.065	1,211
Nigeria 2010	1.04	0.73	1.49	0.826	0.88	0.61	1.28	0.496	1,410
Rwanda 2005	0.63	0.30	1.32	0.22	0.69	0.30	1.61	0.393	1,135
Rwanda 2007-08	0.79	0.44	1.43	0.436	0.79	0.43	1.44	0.436	1,659
Rwanda 2010	0.87	0.39	1.95	0.738	0.81	0.34	1.93	0.628	1,180
Senegal 2005	1.56	0.87	2.82	0.138	1.72	0.94	3.15	0.076	819
Senegal 2008-09	0.99	0.65	1.51	0.965	0.90	0.58	1.40	0.642	1,132
Sierra Leone 2008	1.02	0.92	1.69	0.931	1.06	0.62	1.81	0.825	727
Swaziland 2007	--	--	--	--	--	--	--	--	704
Tanzania 2004-05	0.62	0.40	0.95	0.028	0.82	0.50	1.35	0.441	2,441
Tanzania 2007-08	1.25	0.89	1.75	0.195	1.27	0.83	1.92	0.267	2,102
Tanzania 2010	0.72	0.48	1.09	0.121	0.70	0.46	1.07	0.100	2,147
Uganda 2006	0.63	0.36	1.10	0.105	0.61	0.33	1.14	0.121	760
Uganda 2009-10	0.69	0.42	1.14	0.146	0.68	0.43	1.08	0.102	1,048
Zimbabwe 2005-06	0.55	0.13	2.27	0.411	0.54	0.13	2.37	0.416	1,266
Zimbabwe 2010-2011	0.62	0.25	1.49	0.282	0.65	0.27	1.56	0.331	1,262
Pooled					0.84	0.70	1.02	0.080	25,029

* Adjusted models control for urban/rural residecence, wealth quintile, multiple birth status, mother's education, sex, age, and history of recent fever.

Figure 10. Adjusted odds ratios of moderate-to-severe anemia in last-born children age 6–23 months comparing ITN users with nonusers, by survey and pooled across survey*



* Madagascar 2003-04 has very large 95% CI and ITN use in Swaziland perfectly predicts anemia, so both are dropped from the figure (although they remain in the pooled model). These models control for urban-rural residence, wealth quintile, multiple birth status, mother's education, sex, age, and history of recent fever.
Test for heterogeneity I^2 = 80.0%, p<0.0005.

Table 3 presents results of the multi-country pooled logistic regression analysis. In addition to ITN use that was marginally protective against anemia, other variables that had a significant protective effect on anemia were highest wealth quintile, higher level of mother's education, and female sex. Variables that had a significant negative effect on anemia were multiple birth status, and history of recent fever. Pearson goodness-of-fit testing revealed good model fit (F = 1.09, p = 0.37); however, the I2 test of heterogeneity suggests that fixed effects models might not be sufficient for controlling for heterogeneity.

Table 3. Pooled analyses of most recent DHS/MIS surveys for each country between 2001 and 2011 containing ITN use and hemoglobin data in last-born children age 6-23 months, as well as information on relevant covariates*

	Odds Ratio	95% Confidence Interval		p-value
ITN use				
No	Ref.			
Yes	0.84	0.70	1.02	0.08
Residence				
Urban	Ref.			
Rural	1.23	0.94	1.61	0.136
Wealth Quintile				
Lowest	Ref.			
Second	0.98	0.81	1.19	0.86
Middle	0.96	0.78	1.19	0.712
Fourth	0.81	0.64	1.02	0.076
Highest	0.54	0.39	0.75	<0.0005
Multiple Birth Status				
Singleton	Ref.			
Twin or more	2.34	1.53	3.59	<0.0005
Mother's Education				
No education	Ref.			
Primary	0.77	0.65	0.93	0.005
Secondary+	0.62	0.48	0.79	<0.0005
Child's Sex				
Male	Ref.			
Female	0.78	0.67	0.90	0.001
Child's Age				
6-11 months	Ref.			
12-17 months	1.11	0.95	1.31	0.191
18-23 months	1.07	0.89	1.30	0.455
Recent Fever				
No	Ref.			
Yes	1.67	1.46	1.93	<0.0005
Total N				25,029

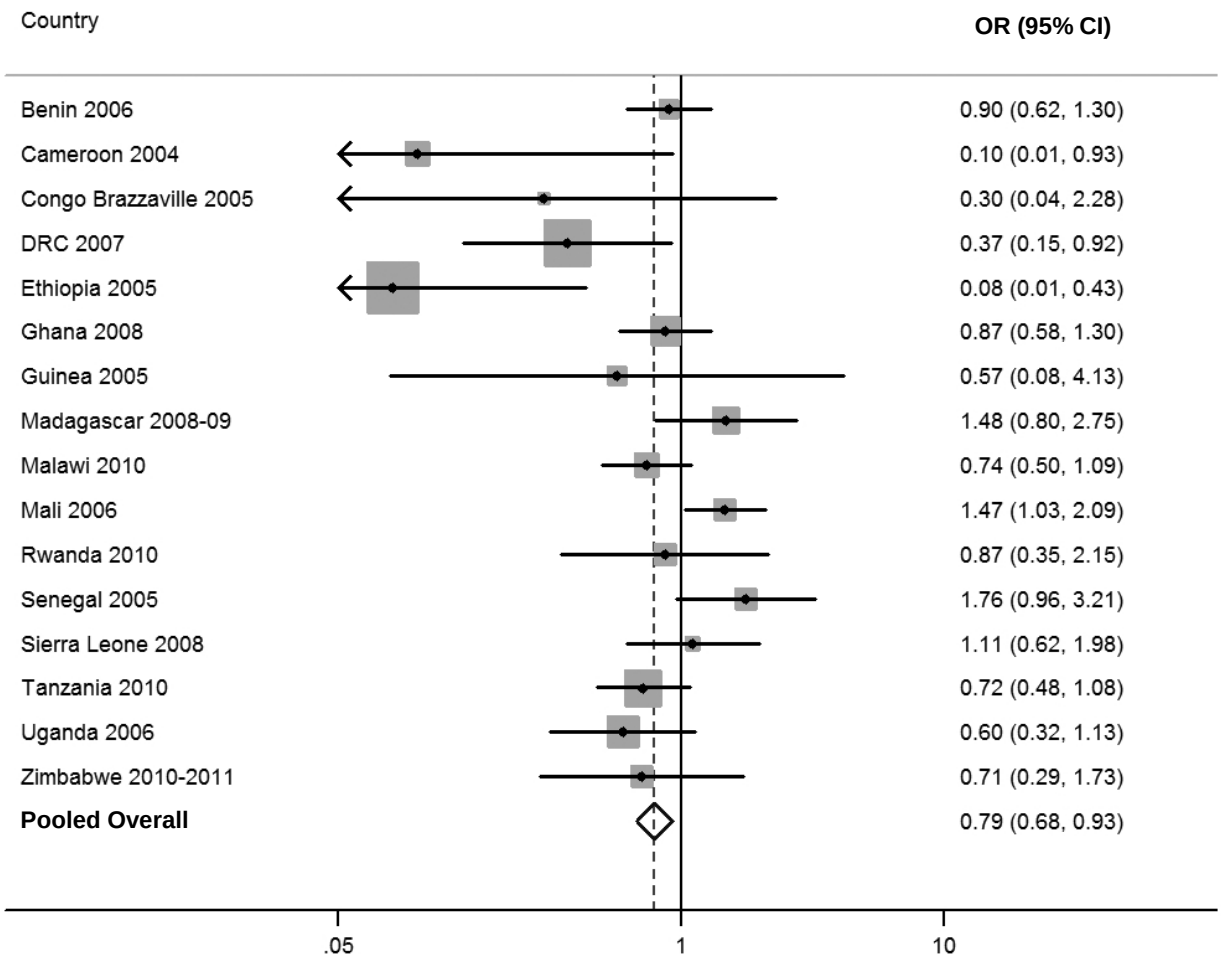
* Surveys include Angola 2011, Benin 2006, Burkina Faso 2003, Cameroon 2004, Congo Brazzaville 2005, DRC 2007, Ethiopia 2005, Ghana 2008, Guinea 2005, Liberia 2009, Madagascar 2008-09, Malawi 2010, Mali 2006, Niger 2006, Nigeria 2010, Rwanda 2010, Senegal 2008-09, Sierra Leone 2008, Swaziland 2007, Tanzania 2010, Uganda 2009-10, and Zimbabwe 2010-11. Dummy variable for survey not shown. Ref. = referent category.

In order to look at the potential confounding effect of immunization status, undernutrition, meat consumption, breastfeeding, and low birth weight on the assocation between ITN use and moderate-to-severe anemia, use of a subset of datasets was necessary. Eighteen of the 22 surveys included in the previous analysis contained questions necessary to look at these additional factors. Figure 11 and Table 4 present the results.

Figure 11 depicts adjusted odds ratios of moderate-to-severe anemia in last-born children age 6-23 months who used ITNs compared with children who did not. AOR and 95% confidence intervals are shown for each survey, as well as for a model in which all survey data are pooled. In Ethiopia 2005, Cameroon 2004, and DRC 2007, ITN use was found to be negatively associated with anemia even after

adjusting for these additional covariates. A significant, positive association was evident between ITN use and anemia in Mali 2006. Survey-specific estimates of the adjusted odds ratios for Burkina Faso 2003 and for Madagascar 2003-04 were large but also had large confidence intervals, indicating unstable estimates. ITN use perfectly predicted anemia in the Swaziland 2007 data, which prohibited calulation of variance in the association between the two variables. Estimates for these three surveys were excluded from Figure 9 for these reasons; however, the survey data were used in the pooled model. Results from the pooled model show a significant negative association between ITN use and odds of moderate-to-severe anemia in last-born children age 6–23 months (OR=0.79; 95% CI =0.68-0.93). More detailed results of the pooled model are shown in Table 6.

Figure 11. Adjusted odds ratios of moderate-to-severe anemia in last-born children age 6–23 months who used ITNs the night before interview compared with those who did not*



* Madagascar 2003-04 and Burkina Faso 2003 are unstable with large 95% CI, and ITN use in Swaziland perfectly predicts anemia, and so these were dropped from the figure (although they remain in the pooled model). These models control for urban-rural residence, wealth quintile, multiple birth status, mother's education, sex, child's age, and history of recent fever, stunting, immunization, meat consumption, breastfeeding, and low birth weight. Test of heterogeneity statistic I^2 = 90.9%; p<0.0005.

The pooled, mutli-country logistic regression model of moderate-to-severe anemia shows that the protective effect of ITN use on anemia persists in models controlling for these additional covariates (Table 4). Last-born children age 6-23 months who used an ITN the night before interview had 0.79 lower odds of having hemoglobin levels less than 8g/dl than children who did not use an ITN the previous night, controlling for residence, wealth quintile, multiple birth status, mother's educational level, child's sex, child's age, child's history of recent fever, child's nutritional status (stunting), child's immunization status, child's recent meat consumption, child's breastfeeding status, and child's history of low birth weight (OR= 0.79; 95% CI = 0.68-0.93). In addition to ITN use, odds of moderate-to-severe anemia were lower in children from the highest wealth quintile compared with the lowest (OR=0.66; 0.46-0.93), in children whose mothers had secondary or higher level of education compared with no education (OR = 0.71, 0.55-0.92), and in female children (OR= 0.81, 0.70-0.94. Odds of moderate-to-severe anemia were higher in children who were part of a multiple birth (OR=2.16, 1.46-3.19), those who had recent fever (OR = 1.60, 1.39-1.85), and those who were stunted (OR = 1.20, 1.02-1.41). I^2 test of heterogeneity suggests that fixed effects models might not be sufficient for controlling for heterogeneity.

Table 4. Multivariable logistic regression pooling the most recent DHS/MIS surveys for each country between 2001 and 2011 containing ITN use and hemoglobin level data in last-born children age 6-23 months, as well as information on relevant covariates*

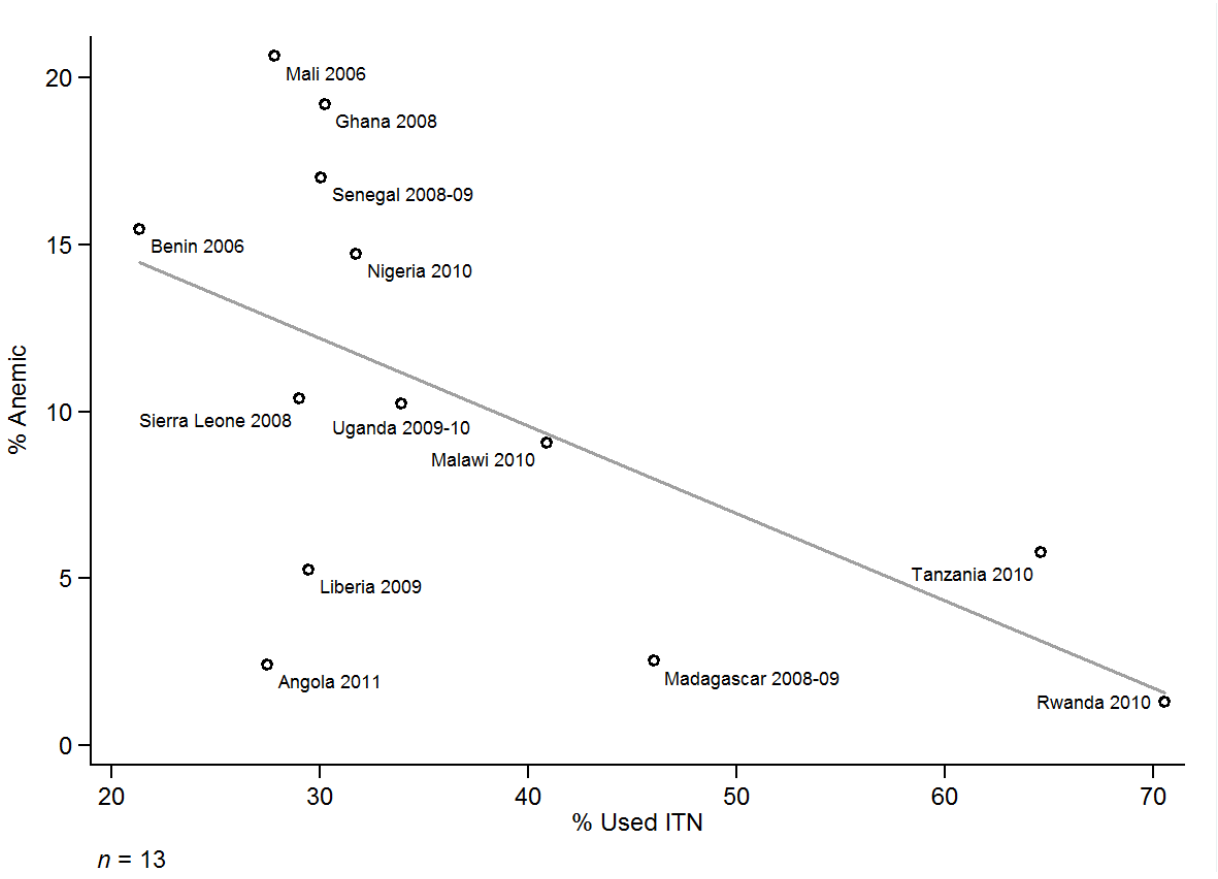
	Odds Ratio	95% Confidence Interval		p-value
ITN use				
No	Ref.			
Yes	0.79	0.68	0.93	0.003
Residence				
Urban	Ref.			
Rural	1.21	0.93	1.56	0.155
Wealth Quintile				
Lowest	Ref.			
Second	0.94	0.77	1.16	0.574
Middle	0.93	0.74	1.18	0.571
Fourth	0.88	0.69	1.13	0.329
Highest	0.66	0.46	0.93	0.017
Multiple Birth Status				
Singleton	Ref.			
Twin or more	2.16	1.46	3.19	<0.0005
Mother's Education				
No education	Ref.			
Primary	0.85	0.71	1.02	0.087
Secondary+	0.71	0.55	0.92	0.011
Child's Sex				
Male	Ref.			
Female	0.81	0.70	0.94	0.005
Child's Age				
6-11 months	Ref.			
12-17 months	0.95	0.80	1.14	0.589
18-23 months	0.84	0.68	1.03	0.093
Recent Fever				
No	Ref.			
Yes	1.60	1.39	1.85	<0.0005
Stunting				
No	Ref.			
Yes	1.20	1.02	1.41	0.026
Full Immunization				
No	Ref.			
Yes	1.00	0.84	1.20	0.977
Meat Consumption				
No	Ref.			
Yes	0.94	0.81	1.10	0.470
Breastfeeding				
No	Ref.			
Yes	0.92	0.77	1.10	0.365
Low Birth Weight				
No	Ref.			
Yes	1.09	0.91	1.30	0.340
Total N				18,588

* Surveys include Benin 2006, Burkina Faso 2003, Cameroon 2004, Congo Brazzaville 2005, DRC 2007, Ethiopia 2005, Ghana 2008, Guinea 2005, Madagascar 2008-09, Malawi 2010, Mali 2006, Rwanda 2010, Senegal 2005, Sierra Leone 2008, Swaziland 2007, Tanzania 2010, Uganda 2006, and Zimbabwe 2010-11. Dummy variable for survey not shown. Ref. = referent category.

3.1.3 Low ITN versus High ITN

Based on the large number of countries with low ITN use (and thus potentially unstable estimates of association between ITN use and anemia), analyses were stratified by level of ITN use. Surveys in which more than 20% of last-born children under age 6-23 months used ITNs the night before the interview were examined as one group, and those with less than 20% using ITNs were examined as a separate group.

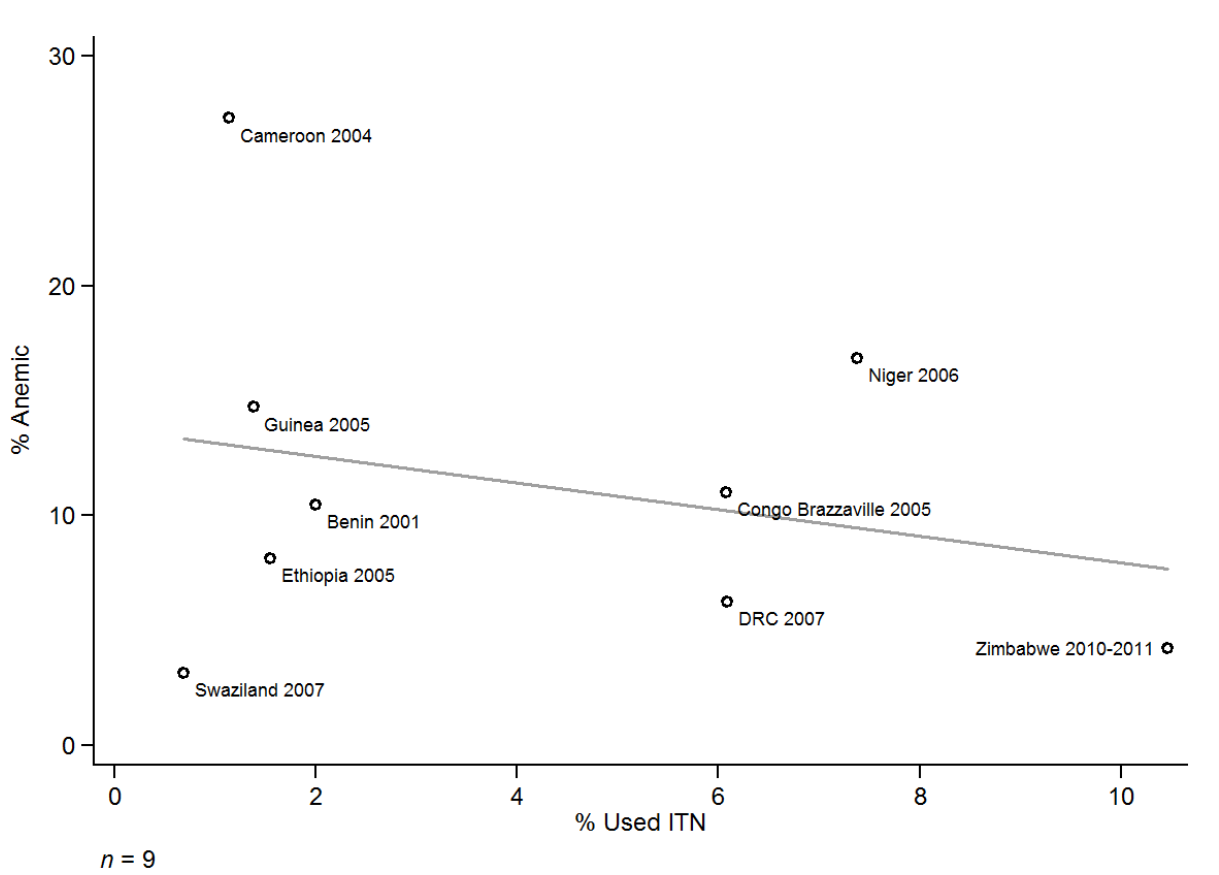
Figure 12. Scatterplot of proportion of last-born children age 6-23 months who used an ITN the night preceding interview by the proportion with moderate-to-severe anemia in surveys with ITN use greater than 20%



Note: OR based on exponentiated slope of line = 0.769. R^2=34.5%

Figure 12 shows the relationship between ITN use and moderate-to-severe anemia in last-born children age 6–23 months limited to countries in which ITN use in the target population was greater than 20%. Each dot on this graph represents a survey (country, year). The best-fit line (slope) exponentiated, estimates the odds of moderate-to-severe anemia per 1% increase in ITN use. As illustrated, the odds of anemia decrease with increasing ITN use (OR = 0.77).

Figure 13. Scatterplot of proportion of last-born children age 6-23 months who used an ITN the night preceding interview by the proportion with moderate-to-severe anemia in surveys with ITN use less than 20%



Note: OR based on exponentiated slope of line = 0.560. R2=7.3%

Figure 13, which also shows the relationship between ITN use and moderate-to-severe anemia in last-born children age 6–23 months, contains only surveys in which ITN use was less than 20%. As illustrated, the odds of anemia decrease with increasing ITN use (OR = 0.56).

Figures 12 and 13 do not provide statistical evidence that the associations between ITN use and anemia are significant. To address the question of statistical significance, a variable for ITN use at the national level was added to a pooled, multi-country model so that interactions between the effect of individual ITN use and level of ITN use at a national level could be examined.

Results of the pooled multi-country model combining both low ITN use and high ITN use countries shows a marginally significant protective effect of individual ITN use on odds of anemia, controlling for dataset as a dummy variable (OR = 0.84; 95% CI = 0.70–1.02; see Table 3).

When an interaction term between individual ITN use and a variable for high/low ITN use at the country level is added to this model, we see a significant interaction between the two (Table 5). This indicates that the effect of individual ITN use is not the same in countries with high ITN use as in countries with low ITN use. In a full, multivariate model, controlling for residence (urban-rural), wealth quintile, multiple birth status, child's sex, child's age, recent history of fever, and with a dummy variable for country, ITN

users in high ITN use countries were shown to have 0.89 the odds of anemia as ITN users in low ITN use countries. In high ITN use countries, individual ITN users had 0.79 times the odds of anemia as non-ITN users (compare to the exponentiated slope in Figure 12), whereas in low ITN use countries, individual ITN users had 0.43 times the odds of anemia as non-ITN users (compare with the exponentiated slope in Figure 13).

Table 5. Pooled, multivariate logistic regression of moderate-to-severe anemia: interaction effect between a child's ITN use and the national prevalence of ITN use*

	Odds Ratio	95% Confidence Interval		p-value
ITN Use				
No	1.00			
Yes	0.43	0.28	0.68	<0.0005
ITN Use Level				
Low (<20%)	1.00			
High (>20%)	0.39	0.25	0.62	<0.0005
ITN Use* ITN Level				
No* low	1.00			
Yes* high	2.04	1.25	3.34	0.004
Total N				25,029

* Controlling for dummy for survey, urban-rural residence, wealth quintile, multiple birth status, mother's education, child's sex, child's age category, and recent fever history.

3.2 Section 2: Change over Time

3.2.1 Descriptive Analyses

Having established an association between use of ITNs and severe anemia, the next step was to assess and evaluate the impact of the investments in ITNs over the last decade. What has been gained by increased ITN coverage? This section examines a subset of countries in which at least two DHS/MIS surveys have been conducted in which data were collected on ITN use and hemoglobin levels in children, as well as on a variety of other covariates that could contribute to changes in the prevalence of anemia. For each country, the surveys were conducted about five years apart.

Figure 14 clearly shows reductions in prevalence of moderate-to-severe anemia between the baseline and endline surveys in each of the countries examined. Lighter colors represent lower prevalence of anemia. Figure 15 also shows the changes in anemia prevalence in each country between baseline and endline surveys, with 95% confidence intervals around each estimate. Estimates of multicountry pooled baseline and multicountry pooled endline anemia prevalence are indicated in the figure. Significant declines in anemia prevalence are evident in most countries between baseline and endline surveys, the exceptions being Angola (2006–2011), Ghana (2003–2008), Mali (2006–2010), and Zimbabwe (2005/6–2010/11), where changes were not significant, and Senegal (2005–2008/9), where prevalence of moderate-to-severe anemia significantly increased.

Figure 14. Prevalence of moderate-to-severe anemia in last-born children age 6–23 months by country and year of survey

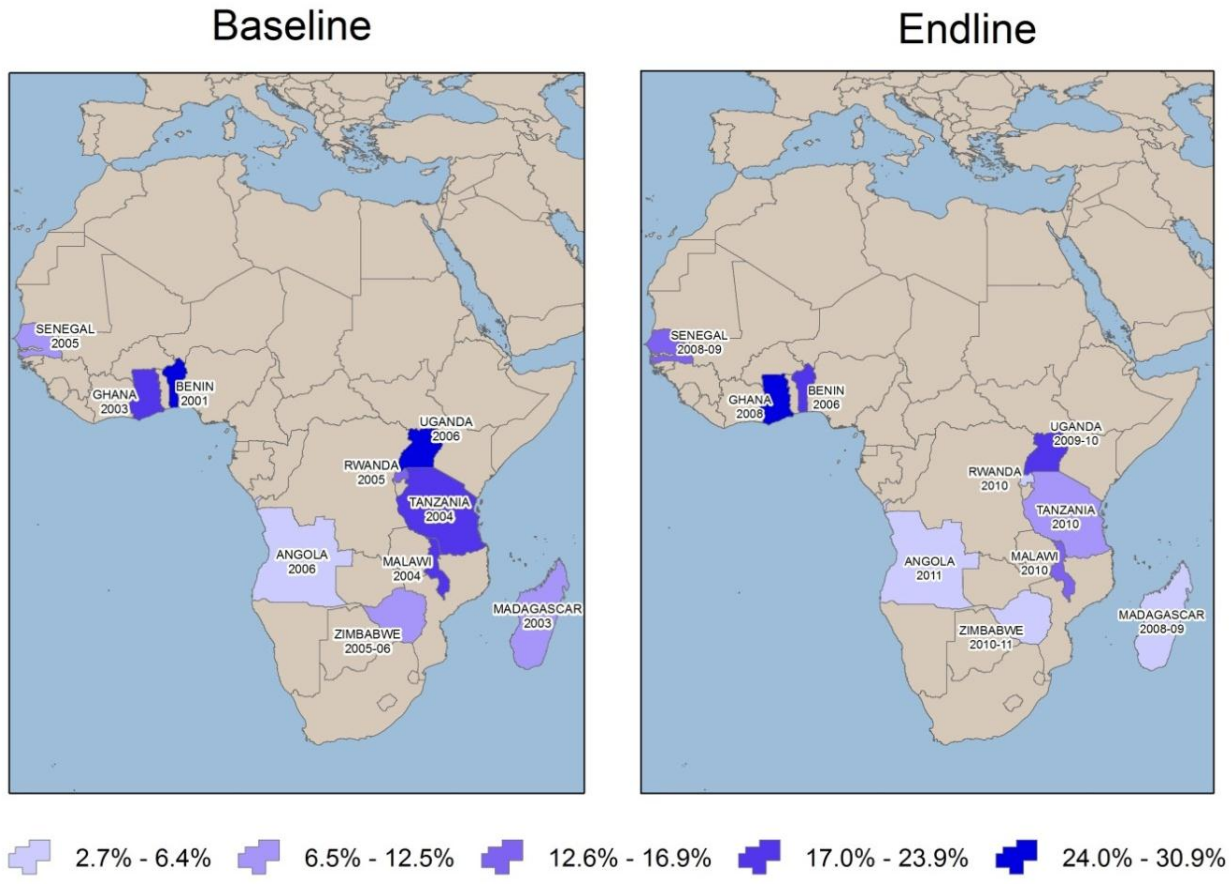
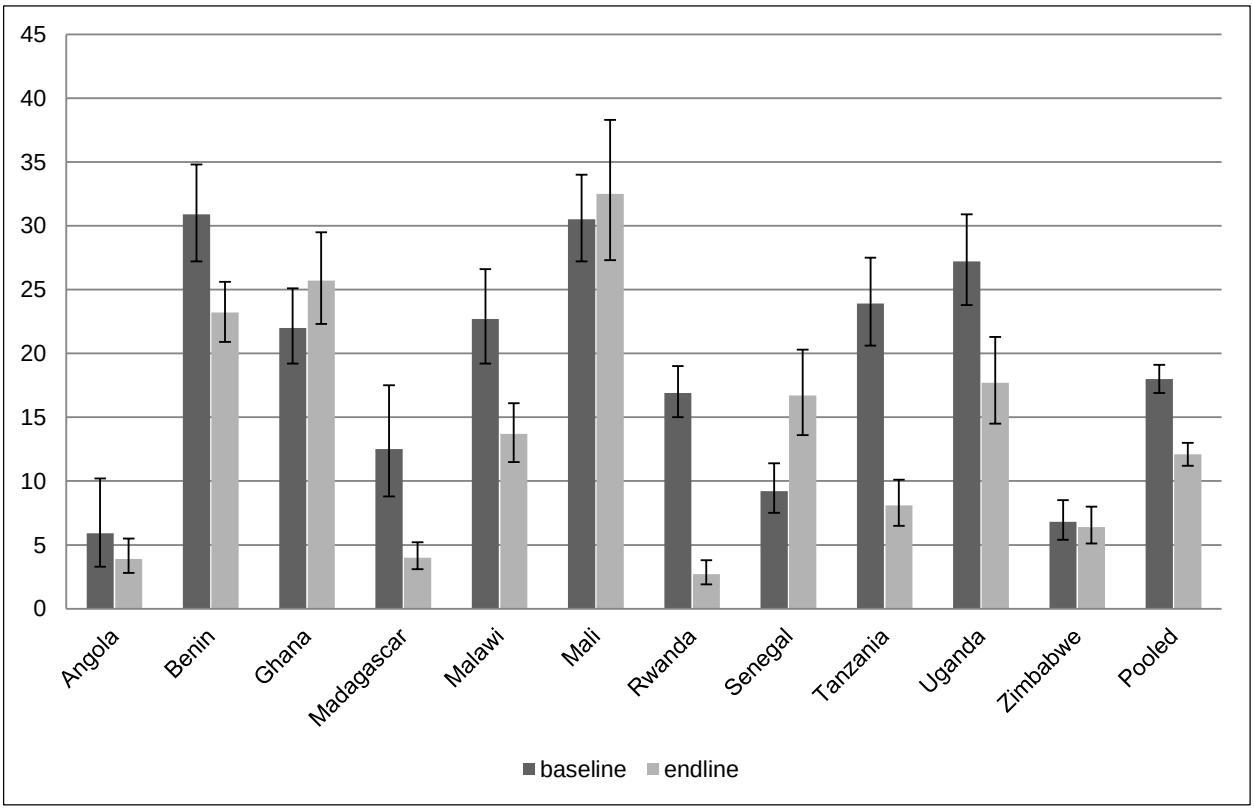
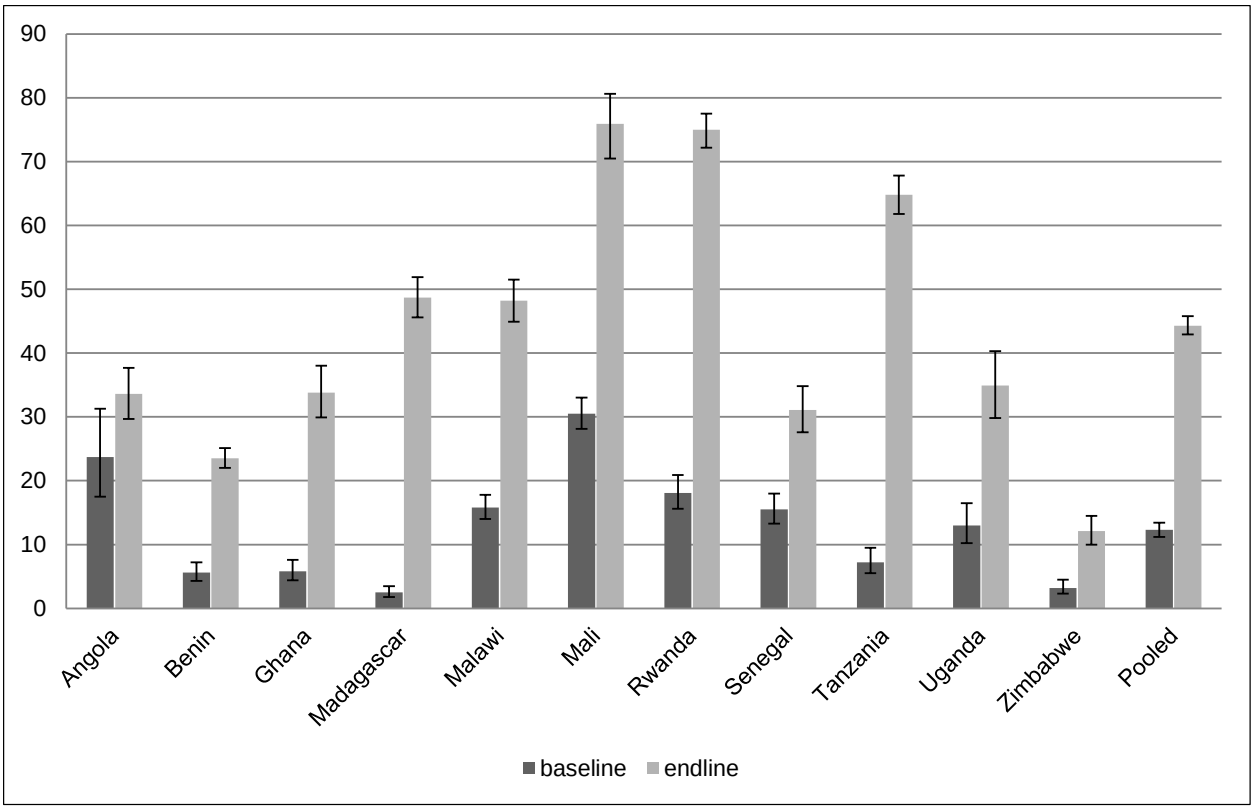


Figure 15. Prevalence of moderate-to-severe anemia in last-born children age 6-23 months in countries with two nationally representative DHS or MIS surveys for comparison



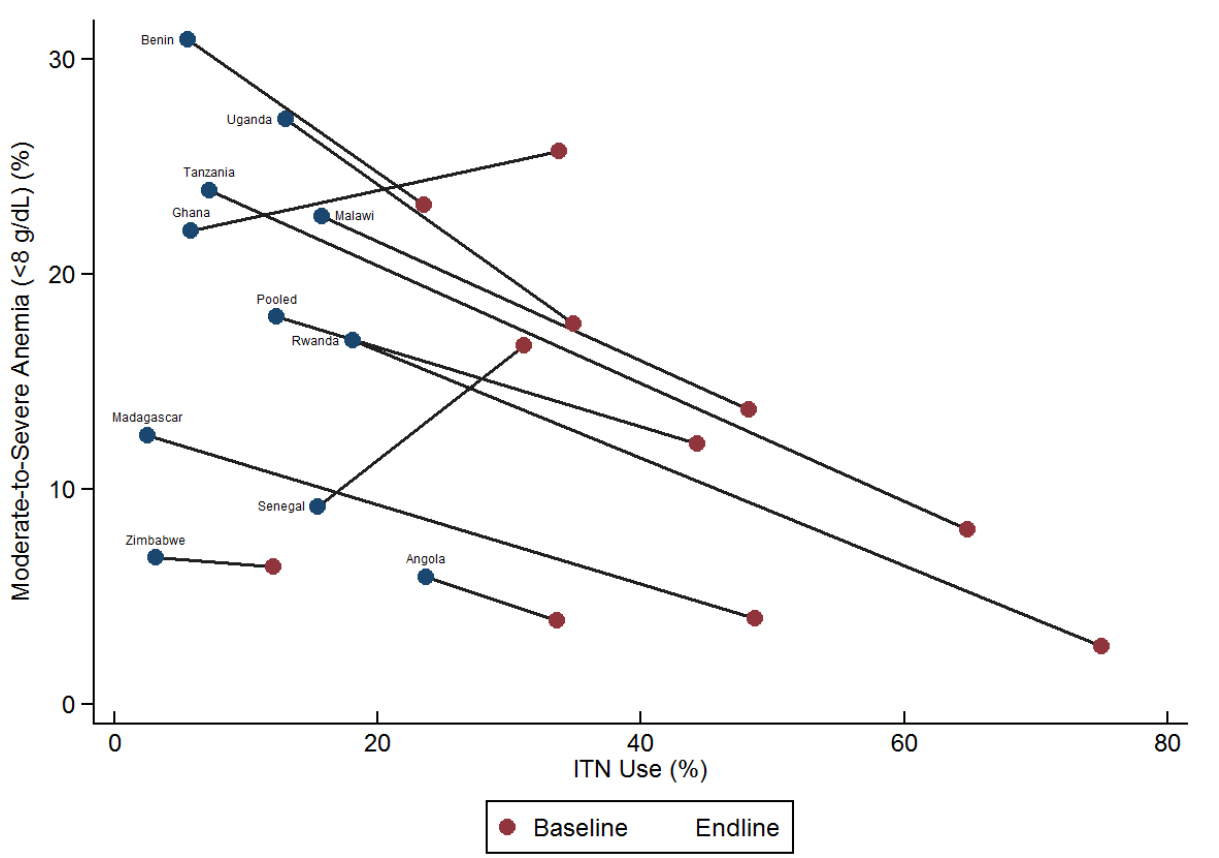
The proportion of last-born children age 6–23 months using ITNs increased significantly in all countries between baseline and endline, except for Angola where the change was not significant (Figure 16). Comparisons of multi-country pooled baseline to multi-country pooled endline values show substantial and significant increases in ITN use in this population, from 12% to 44%.

Figure 16. The prevalence of ITN use among last-born children age 6-23 months in countries with two nationally representative DHS or MIS surveys for comparison



As Figure 17 indicates, in most countries, as ITN use increased between baseline and endline surveys, prevalence of moderate-to-severe anemia decreased (negative slopes). The few exceptions are Mali, Ghana, and Senegal, where prevalence of anemia increased despite increases in ITN use at the national level.

Figure 17. Baseline and endline estimates of the proportion of last-born children age 6–23 months using ITNs and the prevalence of moderate-to-severe anemia at the national level*



* Note: Mali was removed from this figure, as it is an outlier.

3.2.2 Multivariable Analyses

Despite the different levels of ITN use observed between baseline and endline surveys, and the general trend of decreasing anemia prevalence, comparisons between baseline and endline of the unadjusted odds ratios of the association between ITN use and anemia do not support differential effects of ITNs on anemia over time; pooled baseline and pooled endline odds ratios are not significantly different from each other (Table 6). ITN use is associated with lower odds of anemia in Benin (Baseline: OR=0.26, 95%CI=0.09–0.78; Endline: OR=0.68, 95%CI=0.48–0.95), Malawi (Endline: OR=0.69, 95%CI=0.47–1.00), Tanzania (Baseline: OR = 0.62, 95%CI=0.40–0.95), and in pooled models (Baseline: OR=0.68, 95%CI=0. 54–0.87; Endline: OR=0.65, 95%CI=0.55–0.77). Estimates of odds ratios from Madagascar and Angola have wide confidence intervals, indicating unstable estimates. The Mali 2010 survey does not contain necessary covariate information; thus Mali was excluded from adjusted analyses.

Table 6. Unadjusted and adjusted odds ratios of anemia in last-born children age 6-23 months who used an ITN the previous night compared with those who did not

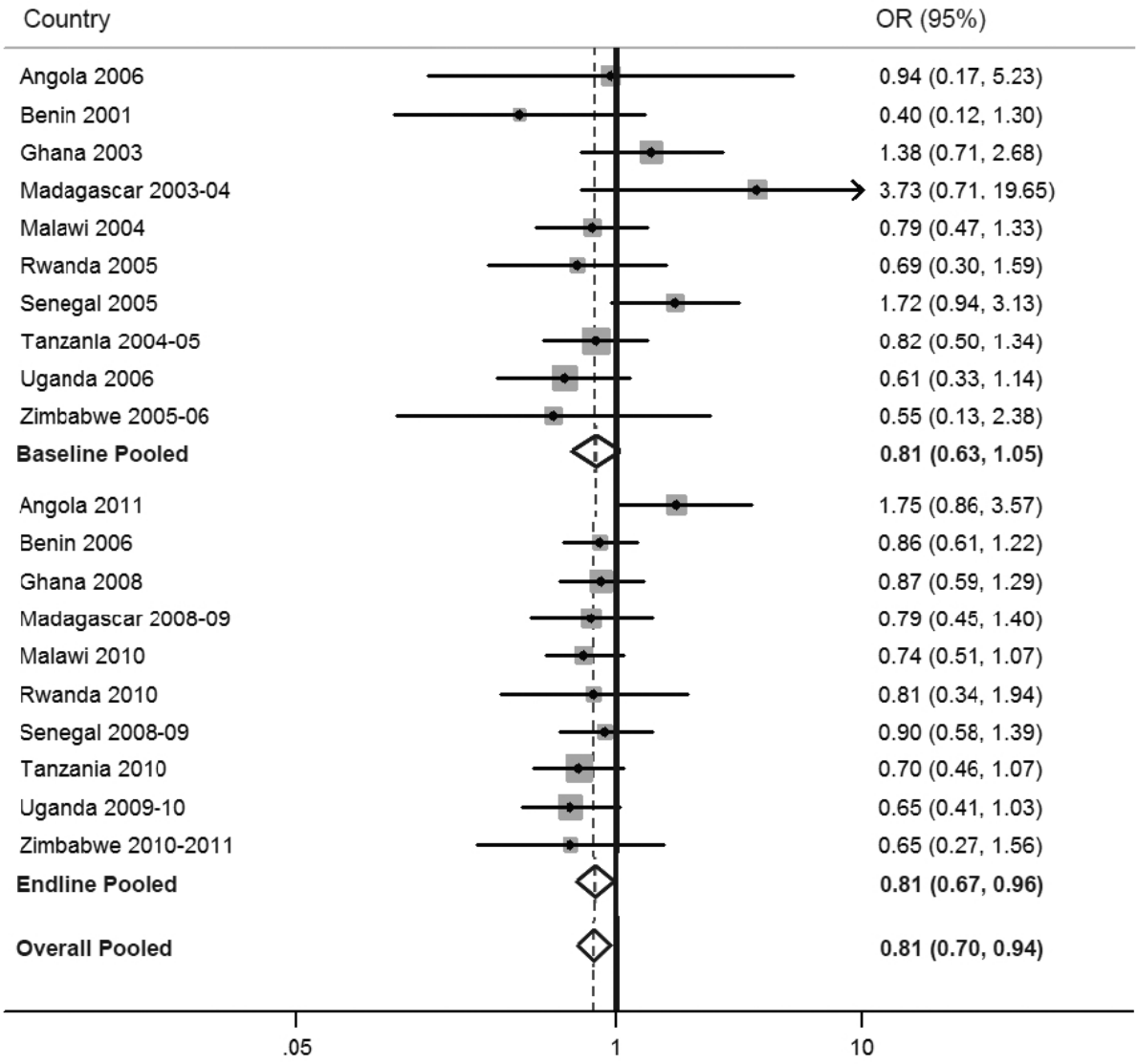
		Unadjusted				Adjusted*				
Timing		**OR**	**LCI**	**UCI**	**p-value**	**OR**	**LCI**	**UCI**	**p-value**	**N**
Baseline	Angola 2006	0.55	0.12	2.50	0.435	0.94	0.16	5.32	0.939	255
Endline	Angola 2011	1.66	0.83	3.33	0.152	1.75	0.86	3.60	0.124	1,040
Baseline	Benin 2001	0.26	0.09	0.78	0.017	0.40	0.12	1.31	0.129	736
Endline	Benin 2006	0.68	0.48	0.95	0.024	0.86	0.60	1.21	0.383	1,383
Baseline	Ghana 2003	1.30	0.71	2.38	0.391	1.38	0.71	2.70	0.338	961
Endline	Ghana 2008	0.79	0.54	1.16	0.227	0.87	0.59	1.30	0.498	717
Baseline	Madagascar 2003-04	1.23	0.29	5.30	0.776	3.73	0.70	19.82	0.122	613
Endline	Madagascar 2008-09	1.74	0.99	3.04	0.053	0.79	1.01	3.16	0.046	1,562
Baseline	Malawi 2004	0.65	0.38	1.11	0.114	0.79	0.47	1.33	0.376	759
Endline	Malawi 2010	0.69	0.47	1.00	0.051	0.74	0.51	1.07	0.109	1,489
Baseline	Mali 2006	1.24	0.88	1.74	0.210	--	--	--	--	1,169
Endline	Mali 2010	1.29	0.82	2.04	0.273	--	--	--	--	548
Baseline	Rwanda 2005	0.63	0.30	1.32	0.220	0.69	0.30	1.61	0.396	1,135
Endline	Rwanda 2010	0.87	0.39	1.95	0.738	0.81	0.34	1.93	0.628	1,180
Baseline	Senegal 2005	1.56	0.87	2.82	0.138	1.72	0.94	3.15	0.076	816
Endline	Senegal 2008-09	0.99	0.65	1.51	0.965	0.90	0.58	1.40	0.641	1,130
Baseline	Tanzania 2004-05	0.62	0.40	0.95	0.028	0.82	0.50	1.35	0.441	2,441
Endline	Tanzania 2010	0.72	0.48	1.09	0.121	0.70	0.46	1.07	0.099	2,146
Baseline	Uganda 2006	0.63	0.36	1.10	0.105	0.61	0.33	1.15	0.126	759
Endline	Uganda 2009-10	0.69	0.42	1.14	0.146	0.65	0.41	1.04	0.072	1,043
Baseline	Zimbabwe 2005-06	0.55	0.13	2.27	0.411	0.55	0.13	2.40	0.427	1,264
Endline	Zimbabwe 2010-2011	0.62	0.25	1.49	0.282	0.65	0.27	1.56	0.331	1,262
Baseline	Pooled	0.68	0.54	0.87	0.002	0.81	0.63	1.05	0.110	9,822
Endline	Pooled	0.65	0.55	0.77	<0.0005	0.81	0.67	0.96	0.018	12,967
Overall	Pooled					0.81	0.70	0.94	0.005	22,802

* Adjusted for urban-rural residence, wealth quintile, multiple births, mother's education, sex, age, mother's age, and recent fever. Pooled models are also adjusted for a dummy variable for survey. LCI = lower confidence interval; UCI = upper confidence interval; N = weighted sample size.

Odds of moderate-to-severe anemia in children using ITNs are lower than those of children not using ITNs in most surveys after controlling for other covariates, but not significantly so (Table 7, Figure 18).

Endline adjusted odds ratios (AOR) and overall AOR combining endline and baseline surveys do show significant protection of ITN use controlling for residence, wealth quintile, multiple birth status, level of mother's education, sex of chld, mother's age and recent fever (baseline: AOR=0.81, 95%CI=0.63–1.05; endline: AOR=0.81, 95%CI=0.67–0.96; overall: AOR=0.81, 95%CI=0.7–0.94).

Figure 18. Adjusted odds ratios of moderate-to-severe anemia in last-born children age 6-23 months who used an ITN the previous night compared with those who did not*



*Adjusted for urban-rural residence, wealth quintile, multiple births, mother's education, sex, age, mother's age, and recent fever. Baseline pooled I^2 test for heterogeneity = 33.8% (p=0.138). Endline pooled I^2 test for heterogeneity = 0.0% (p=0.661). Overall pooled I^2 test for heterogeneity = 10.9% (p=0.319).

The multi-country, pooled model of moderate-to-severe anemia shows a protective effect of ITN use, controlling for residence, wealth quintile, multiple birth status, mother's educational level, child's sex, child's age, and history of recent fever (Table 7). Last-born children age 6–23 months who used an ITN had 0.81 times the odds of anemia as those who did not use an ITN (95% CI =0.70-0.94). Other variables that were significantly associated with lower odds of anemia include middle, fourth and highest wealth quintile relative to lowest (OR = 0.83, 0.73 and 0.53, respectively), female compared to male (OR = 0.83; 95% CI = 0.75-0.93), and age 18-23 months compared with age 6-11 months (OR = 0.77; 95% CI = 0.67-0.88). Being a twin birth and having a fever in the past two weeks were associated with increased odds of

anemia (OR = 2.19; 95% CI = 1.59-3.06 and OR = 1.82; 95% CI = 1.61-2.05, respectively). I2 tests for heterogeneity suggest that fixed effects models are sufficient to control for heterogeneity.

Table 7. Pooled logistic regression model of likelihood of anemia in last-born children age 6-23 months in countries with a baseline and endline DHS/MIS survey containing relevant covariates*

	Odds Ratio	95% Confidence Interval		p-value
ITN Use				
No	Ref.			
Yes	0.81	0.70	0.94	0.005
Residence				
Urban	Ref.			
Rural	1.22	1.02	1.47	0.034
Wealth Quintile				
Lowest	Ref.			
Second	0.92	0.80	1.07	0.291
Middle	0.83	0.70	0.97	0.022
Fourth	0.73	0.61	0.87	0.001
Highest	0.53	0.41	0.67	<0.0005
Multiple Birth Status				
Singleton	Ref.			
Twin or more	2.19	1.56	3.06	<0.0005
Mother's Education				
No education	Ref.			
Primary	0.92	0.81	1.05	0.222
Secondary+	0.83	0.68	1.02	0.075
Child's Sex				
Male	Ref.			
Female	0.83	0.75	0.93	0.001
Child's Age				
6-11 months	Ref.			
12-17 months	0.99	0.87	1.12	0.863
18-23 months	0.77	0.67	0.88	<0.0005
Recent Fever				
No	Ref.			
Yes	1.82	1.62	2.05	<0.0005
Total N				22,802

* With dummy variable for survey included in the model. Countries include Angola, Benin, Ghana, Madagascar, Malawi, Rwanda, Senegal, Tanzania, Uganda, and Zimbabwe.

To examine the effect of time between surveys on the outcome, a multivariate, multi-country, pooled model of moderate-to-severe anemia was created controlling for covariates as well as for a variable identifying baseline and endline surveys and a dummy variable for country. An interaction term between ITN use and the baseline variable was added to see if the association between ITN use and anemia varied significantly between baseline and endline surveys.

Table 8. Multivariate, pooled logistic regression analysis of moderate-to-severe anemia in last-born children age 6-23 months, looking at effect of survey timing on ITN use-anemia association*

	Odds Ratio	95% Confidence Interval		p-value
ITN Use				
No	Ref.			
Yes	0.84	0.65	1.09	0.194
Survey Year				
Baseline	Ref.			
Endline	0.69	0.60	0.79	<0.0005
ITN Use*Survey Year				
No* Baseline	Ref.			
Yes* Endline	0.88	0.65	1.19	0.409
Total N				22,802

* Controlling for country with a dummy variable as well as for urban-rural residence, wealth quintile, mother's education, child's sex, child's age, and recent fever history. Countries include Angola, Benin, Ghana, Madagascar, Malawi, Rwanda, Senegal, Tanzania, Uganda, and Zimbabwe.

Results in Table 8 show no significant difference in the effect of ITN use on anemia between baseline and endline surveys controlling for country and other covariates (OR = 0.88, 95%CI = 0.65-1.19). These results do not indicate that ITN use is not an important determinant of anemia among young children, but rather that the effect of ITN use on anemia does not vary by timing of the survey.

If additional covariates are added to the model, in a subset of countries for which the data are available, the interaction between ITN use and survey timing becomes marginally significant (Table 9). Thus, the extent to which the effect of ITN use on anemia varies between baseline and endline surveys could depend on other socio-demographic and health factors.

Table 9. Multivariate, pooled logistic regression analysis of moderate-to-severe anemia in last-born children age 6-23 months, looking at effect of survey timing on association between ITN use and anemia*

	Odds Ratio	95% Confidence Interval		p-value
ITN Use				
No	Ref.			
Yes	1.00	0.74	1.35	0.999
Survey Year				
Baseline	Ref.			
Endline	0.73	0.62	0.87	<0.0005
ITN Use*Survey Year				
No* Baseline	Ref.			
Yes* Endline	0.72	0.51	1.03	0.072
Total N				19,390

* Controlling for country with a dummy variable as well as for urban-rural residence, wealth quintile, mother's education, child's sex, child's age, recent fever history, complete immunization status, stunting, breastfeeding, meat consumption, and low birth weight status. Countries include Benin, Ghana, Madagascar, Malawi, Rwanda, Tanzania, and Zimbabwe.

In order to evaluate the impact of change over time in the use of ITNs on anemia prevalence, a multivariate decomposition for nonlinear response model with deviation contrast normalization for categorical variables was used. This model uses the Oaxaca-Blinder method to produce an estimate of the proportion of the observed decline in anemia prevalence due to increases in ITN use. Table 10 contains a summary of the change in component values between baseline and endline surveys, as well as changes in coefficient values. Results show that the largest compositional change (change in value) of any of the variables was in ITN use (32% increase). No change in the ITN use coefficient was observed.

Table 10. Summary of component values and coefficients from pooled baseline and pooled endline surveys*

Characteristics	Baseline Value (%)	Endline Value (%)	Change In Value	Baseline Coefficient	Endline Coefficient	Change In Coefficient
Type of Place of Residence						
Urban	22.8	21.7	-0.011	Ref	Ref	
Rural	77.2	78.3	0.011	0.162	0.244	-0.08251
Wealth Index						
Poorest	23.5	22.4	-0.011	Ref	Ref	
Poorer	22.1	22.5	0.004	-0.078	-0.074	-0.005
Middle	20.7	20.0	-0.007	-0.233	-0.12	-0.113
Richer	18.9	19.1	0.002	-0.322	-0.308	-0.014
Richest	14.9	16.0	0.011	-0.711	-0.562	-0.149
Mother's Education						
None	29.5	27.3	-0.022	Ref	Ref	
Primary	52.9	53.3	0.004	-0.05378	-0.11845	0.065
Secondary+	17.6	19.4	0.018	-0.10175	-0.268	0.166
Birth						
Singleton	98.5	98.3	-0.002	Ref	Ref	
Multiple Birth	1.5	1.7	0.002	0.718	0.861	-0.143
Child's Age						
6-11 months	34.0	33.9	-0.001	Ref	Ref	
12-17 months	35.0	35.0	0.000	0.077	-0.120	0.197
18-23 months	31.0	31.1	0.001	-0.174	-0.380	0.206
Sex of Child						
Male	50.0	49.3	-0.007	Ref	Ref	
Female	50.0	50.7	0.007	-0.122	-0.252	0.131
Recent Fever						
No	63.3	65.6	0.023	Ref	Ref	
Yes	36.7	34.4	-0.023	0.557	0.657	-0.099
Slept Under ITN Last Night						
No	87.8	55.7	-0.321	Ref	Ref	
Yes	12.2	44.3	0.321	-0.208	-0.208	0.000
Anemia						
No	82.1	87.9	0.058			
Yes	17.9	12.1	-0.058			
Constant				-2.807	-3.156	0.349

* Countries include Angola, Benin, Ghana, Madagascar, Malawi, Rwanda, Senegal, Tanzania, Uganda, and Zimbabwe.

The overall decomposition model results (Table 11) show that compositional change, or a change in mean values for covariates between baseline and endline surveys, accounts for 25% of the observed decrease in moderate-to-severe anemia (equivalent to a decrease of 1.4% in anemia prevalence). Conversely, the change in effect of each variable on the odds of anemia between baseline and endline surveys accounts for 75% of the decrease in anemia (equivalent to a decrease of 4.4% in anemia prevalence). Both of these contributions are significant.

Table 11. Overall decomposition model results: relative contribution of the effects of compositional change in covariates to the change in effect of covariates on the decrease in moderate-to-severe anemia between baseline and endline surveys*

	Coefficient (X100)	95% Confidence Interval		p-value	%
Component	1.46	0.45	2.47	0.005	24.85
Coefficient	4.40	2.81	5.99	<0.0005	75.15
Total	5.85	4.58	7.13	<0.0005	
Total N					16,502

* High outcome group: baseline==1; Low outcome group: baseline==0

Results of detailed decomposition models (Table 12) allow an examination of the effects of individual variables on the change in anemia over time. Holding the effects of ITNs on anemia fixed at baseline levels, the change in ITN use alone (from weighted mean baseline use to weighted mean use at endline) would have accounted for a decrease the prevalence of severe anemia of 18.8% of the observed reduction (equivalent to 1.1% reduction in anemia prevalence). Reductions in prevalence of fever between baseline and endline would have contributed 4.2% of the observed reduction in anemia prevalence (equivalent to a 1.1% reduction in prevalence). Changes in SES variables (wealth index and mother's education) would have decreased prevalence of severe anemia by an insignificant amount (0.09%). Taken together, the compositional changes account for a 25% decrease in anemia.

Change in covariate effects account for an overwhelming amount of the predicted change in severe anemia between baseline and endline (75%). Holding composition fixed at the endline levels (assuming that ITNs were used by 44% of children age 6–59 months), the change in the ITN use effect (the difference in the coefficient for ITN use between the baseline and endline models) would account for 12% of the observed reduction in moderate-to-severe anemia (equivalent to 0.7% decrease in anemia prevalence from observed baseline levels); however, this change is not significant, as the 95% confidence interval includes zero. The same holds for all but one other covariate modeled; the 95% confidence intervals span zero. The change in effect of rural residence (coefficient: 0.16 to 0.24) is the only covariate which would be associated with a significant decrease in moderate-to-severe anemia (7.2% reduction from baseline levels).

Thus, of all the compositional changes, the increase in ITN use between baseline and endline surveys accounts for the largest proportion of the observed decrease in moderate-to-severe anemia, at 19%. Of the 25% of the decrease in anemia that was due to changes in mean covariate values, the majority of the effect, 76% (19%/25%), was due to increasing ITN use. Overall, little of the total decrease in anemia can be explained by specific changes in composition or in effect, as 75% is due to changes in effect, and only one of these components (urban-rural residence) is significant.

Table 12. Detailed multivariate decomposition for nonlinear response model results in a multi-country pooled logistic model

	Due to Difference in Composition				
	Coefficient (X 100)	**95% Confidence Interval**		**p-value**	**%**
ITN Use	1.102	0.058	2.145	0.039	18.82
Rural Residence	-0.054	-0.090	-0.017	0.004	-0.91
Lowest Wealth Quintile	0.027	0.003	0.050	0.026	0.46
Second Wealth Quintile	-0.010	-0.021	0.000	0.050	-0.18
Middle Wealth Quintile	0.002	-0.014	0.018	0.848	0.03
Fourth Wealth Quintile	0.001	-0.004	0.006	0.758	0.01
Highest Wealth Quintile	0.051	0.011	0.091	0.012	0.88
Multiple Birth	-0.023	-0.035	-0.011	<0.0005	-0.39
No Education	0.059	0.022	0.095	0.002	1.00
Primary	0.002	-0.003	0.007	0.458	0.03
Secondary or More	0.039	-0.002	0.079	0.064	0.66
Female	0.011	-0.004	0.027	0.158	0.19
6-11 Months	0.001	-0.001	0.002	0.442	0.01
12-17 Months	-0.001	-0.001	0.000	0.024	-0.01
18-23 Months	0.002	0.001	0.003	0.004	0.03
Recent Fever	0.247	0.189	0.306	<0.0005	4.22

	Due to Difference in Coefficients				
	Coefficient (X 100)	**95% Confidence Interval**		**p-value**	**%**
ITN Use	0.69	-0.75	2.13	0.347	11.77
Rural Residence	7.20	0.70	13.71	0.030	123.02
Lowest Wealth Quintile	-0.36	-0.84	0.13	0.151	-6.09
Second Wealth Quintile	-0.27	-0.77	0.24	0.302	-4.57
Middle Wealth Quintile	-0.25	-0.72	0.22	0.291	-4.32
Fourth Wealth Quintile	0.28	-0.20	0.77	0.250	4.85
Highest Wealth Quintile	0.41	-0.14	0.96	0.143	7.03
Multiple Birth	-0.01	-0.12	0.11	0.890	-0.14
No Education	0.10	-0.38	0.58	0.686	1.70
Primary	0.87	-0.03	1.76	0.057	14.86
Secondary or More	-0.39	-0.85	0.07	0.098	-6.64
Female	2.14	-1.31	5.58	0.224	36.54
6-11 Months	-0.40	-0.94	0.15	0.153	-6.77
12-17 Months	0.16	-0.40	0.72	0.565	2.81
18-23 Months	0.22	-0.31	0.74	0.418	3.71
Recent Fever	-0.03	-0.83	0.78	0.947	-0.46
Constant	-5.98	-13.31	1.35	0.110	-102.18

Similar results are found after further restricting the sample of surveys to those that included additional covariates such as anthromopetric measures, immunization history, dietary information, and history of low birth weight. ITN use in last-born children age 6–23 months is associated with decreased odds of moderate-to-severe anemia (OR=0.80; 95% CI=0.69–0.94) even controlling for these additional covariates, as well as for dataset and survey year (Table 13). Of the additional covariates added to this model, only stunting (height-for-age more than 2 standard deviations below the mean) was significantly associated with anemia (OR = 1.20; 95% CI = 1.38–1.85); complete immunization, partial breastfeeding, meat consumption, and low birth weight were not associated with odds of anemia in this adjusted model.

Table 13. Multivariate, pooled logistic regression model of likelihood of anemia in last-born children age 6-23 months with additional covariates*

	Odds Ratio	95% Confidence Interval		p-value
ITN Use				
No	Ref.			
Yes	0.84	0.69	1.02	0.072
Residence				
Urban	Ref.			
Rural	1.04	0.79	1.36	0.797
Wealth Quintile				
Lowest	Ref.			
Second	0.90	0.75	1.07	0.234
Middle	0.74	0.60	0.91	0.004
Fourth	0.62	0.49	0.79	<0.0005
Highest	0.47	0.34	0.65	<0.0005
Parity				
Singleton	Ref.			
Twin or more	2.09	1.31	3.32	0.002
Mother's Education				
No education	Ref.			
Primary	0.85	0.72	1.00	0.053
Secondary+	0.77	0.61	0.97	0.024
Child's Sex				
Male	Ref.			
Female	0.84	0.73	0.96	0.009
Child's Age				
6-11 months	Ref.			
12-17 months	0.94	0.79	1.11	0.434
18-23 months	0.73	0.62	0.87	<0.0005
Recent Fever				
No	Ref.			
Yes	1.79	1.52	2.10	<0.0005
Stunting				
No	Ref.			
Yes	1.24	1.07	1.43	0.003
Full Immunization				
No	Ref.			
Yes	0.97	0.83	1.13	0.659
Meat Consumption				
No	Ref.			
Yes	0.99	0.84	1.16	0.888
Breastfeeding				
No	Ref.			
Yes	0.95	0.79	1.15	0.594
Low Birth Weight				
No	Ref.			
Yes	1.17	0.96	1.42	0.115
Total N				19,390

* Dummy variable for survey also included. Countries include Benin, Ghana, Madagascar, Malawi, Rwanda, Tanzania, and Zimbabwe.

Tables 14 and 15 present results of decomposition models. These results are not directly comparable with those of the previous decomposition model (Tables 11 and 12) as data from a different sample of surveys were used. However, in this model the relative importance of changes in effects of variables (89%) over the importance of changes in composition (11%) in explaining the observed decrease in anemia prevalence is higher than in the previous model. The difference could be a result of the different sample (fewer surveys, the specific countries) or it could be a result of a change due to the composition and effect of the additional covariates (stunting, immunization status, low birth weight, meat consumption, and breastfeeding) added in this model.

Of the changes in composition of covariates that affect changes in anemia between baseline and endline, changes in the prevalence of recent fever were responsible for almost all of the change (10.9%/11.3% = 96.4%). Changes in the percentage of children using ITNs between baseline and endline did not significantly contribute to the observed decrease in anemia between baseline and endline; however, change in the effect of ITN use on anemia from baseline to endline did account for a significant proportion of the observed decrease in anemia. This change alone accounted for 45% of the actual observed difference in anemia between the two periods (equivalent to a 2.8% decrease from baseline anemia prevalence).

Table 14. Overall decomposition model results: relative contribution of the effects of compositional change in covariates to the change in effect of covariates on the decrease in moderate-to-severe anemia between baseline and endline surveys*

	Coefficient (X100)	95% Confidence Interval		p-value	%
Composition	0.70	-1.09	2.48	0.444	11.29
Coefficient	5.47	3.22	7.73	<0.0005	88.71
Total	6.17	4.72	7.62	<0.0005	
Total N					16,502

* High outcome group: baseline==1; Low outcome group: baseline==0

Table 15. Detailed multivariate decomposition for nonlinear response model results in restricted multi-country pooled sample

	Due to Difference in Composition				
	Coefficient (X 100)	**95% Confidence Interval**		**p-value**	**%**
ITN Use	-0.185	-2.288	1.917	0.863	-3.00
Rural Residence	0.011	-0.020	0.041	0.493	0.17
Lowest Wealth Quintile	0.070	0.017	0.123	0.009	1.14
Second Wealth Quintile	-0.098	-0.175	-0.022	0.012	-1.59
Middle Wealth Quintile	0.001	-0.001	0.002	0.508	0.01
Fourth Wealth Quintile	-0.019	-0.046	0.008	0.168	-0.31
Highest Wealth Quintile	0.025	0.007	0.044	0.008	0.41
Multiple Birth	-0.027	-0.051	-0.003	0.026	-0.44
No Education	0.127	0.024	0.231	0.015	2.07
Primary	0.049	-0.048	0.146	0.321	0.80
Secondary or More	-0.063	-0.128	0.002	0.057	-1.03
Female	0.027	-0.011	0.065	0.164	0.44
6-11 Months	0.004	-0.019	0.028	0.724	0.07
12-17 Months	0.029	-0.001	0.059	0.059	0.47
18-23 Months	0.063	-0.003	0.128	0.060	1.02
Recent Fever	0.675	0.251	1.100	0.002	10.94
Stunted	0.047	-0.033	0.126	0.247	0.76
Fully Immunized	-0.127	-0.796	0.542	0.710	-2.06
Consumed Meat	0.085	-0.432	0.602	0.748	1.38
Partially Breastfed	0.001	-0.016	0.017	0.925	0.01
Low Birth Weight	0.003	-0.054	0.059	0.927	0.04

	Due to Difference in Coefficients				
	Coefficient (X 100)	**95% Confidence Interval**		**p-value**	**%**
ITN use	2.79	0.69	4.89	0.009	45.25
Rural residence	4.58	-3.12	12.28	0.244	74.22
Lowest wealth quintile	0.11	-0.51	0.74	0.725	1.82
Second wealth quintile	0.30	-0.36	0.97	0.375	4.87
Middle wealth quintile	-0.03	-0.60	0.55	0.930	-0.42
Fourth wealth quintile	-0.05	-0.63	0.53	0.855	-0.88
Highest wealth quintile	-0.19	-0.84	0.45	0.556	-3.14
Multiple Birth	-0.05	-0.20	0.10	0.513	-0.82
No Education	0.07	-0.47	0.61	0.801	1.13
Primary	1.34	0.24	2.45	0.017	21.76
Secondary or more	-0.50	-0.99	0.00	0.048	-8.05
Female	1.23	-3.06	5.52	0.573	19.97
6-11 months	-0.75	-1.47	-0.03	0.040	-12.21
12-17 months	0.58	-0.12	1.27	0.103	9.36
18-23 months	0.17	-0.52	0.86	0.630	2.75
Recent Fever	0.28	-0.53	1.08	0.501	4.46
Stunted	0.07	-1.09	1.23	0.905	1.14
Fully immunized	0.52	-1.29	2.34	0.572	8.47
Consumed meat	-1.75	-2.93	-0.57	0.004	-28.32
Partially Breastfed	1.64	-1.45	4.73	0.299	26.51
Low birth weight	-0.01	-0.79	0.77	0.982	-0.15
Constant	-4.88	-14.04	4.28	0.297	-79.01

4 Discussion

At the national level in malaria-endemic sub-Saharan African countries, a large range in ITN use by young children and a large range in prevalence of moderate-to-severe anemia are evident. In countries studied, the prevalence of ITN use varies from 1% to 76%, while the prevalence of moderate-to-severe anemia ranges from 3% to 45%. In countries that have conducted more than one nationally representative survey with both malaria intervention questions and testing of hemoglobin levels, clear increases are evident in the proportion of young children who use ITNs over the approximately 5 year span between baseline and endline surveys. This is an important achievement, as young children are at high risk of illness and death from malaria.

In most countries studied, taken individually, ITN use is not associated with odds of moderate-to-severe anemia. When all the countries are pooled in multivariate analyses, however, ITN use is associated with an approximate 20% reduction in odds of anemia in young children. These findings suggest that use of ITNs protects children age 6-23 months from moderate-to-severe anemia, adjusting for other factors that could affect risk of anemia. The fact that this association is not evident in most countries when studied individually could indicate that the national level might not be the most appropriate level to use for studies of malaria control. Malaria can have heterogenous distributions and thus is best studied at smaller geographic areas, such as villages (Ye et al. 2007).

When stratified based on national prevalence of ITN use among children age 6-23 months, children's ITN use is associated with anemia in countries with high ITN use as well as in those with low ITN use. The effect of individual ITN use on anemia differs, however, between children in countries where ITN use is high and where it is low. The effect of ITN use is stronger in countries with low ITN use compared with those with high ITN use. These results may be confounded by factors not controlled for in the analyses, such as small-scale malaria transmission indices, differences in ITN distribution policies, and timing of data collection in relation to that of ITN distribution campaigns.

Another set of analyses was conducted with data from countries where more than one survey was available to study changes over time. These analyses revealed that the effect of ITN use on the odds of anemia in young children did not change significantly between the baseline and endline surveys, controlling for country and other basic socio-demographic variables. When additional child health variables were added into these models, the ITN use-survey period interaction term was marginally significant, indicating that the association is influenced by these other child health factors. Similar results were seen in decomposition models.

Results of decomposition models revealed that, of all of the covariates included, ITN use was the most important compositional variable, accounting for 19% of the observed reduction in anemia prevalence between pooled baseline and pooled endline surveys, which is equivalent to a 1% reduction in anemia prevalence. In a smaller sample of surveys including more child health variables, ITN use was no longer an important compositional variable, but the effect of ITN use on likelihood of anemia was important in determining the decrease in anemia prevalence between baseline and endline surveys. This effect accounted for 45% of the overall anemia decline between baseline and endline (equivalent to a 3% decrease in anemia prevalence from baseline levels). Thus, among the variables included in decomposition models, ITN use was relatively important in the reduction of anemia prevalence over time; however, changes in the composition and effect of ITN use over time accounted for minor declines in anemia prevalence overall (1% and 3%, respectively). This suggests that unmeasured variables may account for much of the observed declines in anemia.

The results of decomposition models suggest that increased distribution of ITNs over the past decade has had significant impact on moderate-to-severe anemia, which is one indicator of malaria morbidity. Although decomposition model results clearly indicate the relative importance of ITNs compared with other variables, the importance of compositional changes compared with effect changes varied, depending on the array of variables included. These results highlight the complex relationships between anemia, malaria, and other indicators of child health.

This study was constrained by some limitations. The use of cross-sectional data does not allow for determination of causal associations. While previous research has determined that anemia can be reasonably used as a measure of impact of malaria control interventions in highly endemic settings (Korenromp et al. 2004), use of anemia as a proxy for malaria morbidity leads to complex interpretation of results, as anemia is not a specific outcome of malaria infection. Due to the complex etiology of anemia and to the changing landscape of malaria transmission in an era of scaling up malaria control interventions, the population attributable fraction (PAF) of anemia due to malaria could vary by country and over time. Finally, the analyses did not consider the effect of level of malaria transmission, and similarly the effect of season. Future analyses might include measures of malaria transmission indices to determine the effect of malaria endemicity on any observed associations between change in ITN ownership/use and change in hemoglobin levels. These types of analyses would likely need to be done on a small geographic scale, due to the often heterogenous endemicity levels of malaria within many countries.

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Appendix

Appendix Table A. DHS/MIS datasets available for inclusion in analyses and those used for Section 1 and Section 2 analyses

All Surveys	Survey Type	Section 1	Section 2
Angola 2006	MIS		X
Angola 2011	MIS	X	X
Benin 2001	DHS		X
Benin 2006	DHS	X	X
Burkina Faso 2003	DHS	X	
Cameroon 2004	DHS	X	
Congo Brazzaville 2005	DHS	X	
DRC 2007	DHS	X	
Ethiopia 2005	DHS	X	
Ghana 2003	DHS		X
Ghana 2008	DHS	X	X
Guinea 2005	DHS	X	
Liberia 2009	MIS	X	
Madagascar 2003-04	DHS		X
Madagascar 2008-09	DHS	X	X
Malawi 2004	DHS		X
Malawi 2010	DHS	X	X
Mali 2006	DHS	X	
Mali 2010	A&P		
Niger 2006	DHS	X	
Nigeria 2010	MIS	X	
Rwanda 2005	DHS		X
Rwanda 2007-08	DHS		
Rwanda 2010	DHS	X	X
Senegal 2005	DHS		X
Senegal 2008-09	MIS	X	X
Sierra Leone 2008	DHS	X	
Swaziland 2007	DHS	X	
Tanzania 2004-05	DHS		X
Tanzania 2007-08	MIS		
Tanzania 2010	DHS	X	X
Uganda 2006	DHS		X
Uganda 2009-10	MIS	X	X
Zimbabwe 2005-06	DHS		X
Zimbabwe 2010-11	DHS	X	X

Appendix Table B. Prevalence of moderate-to-severe anemia in last-born children age 6-23 months

Dataset	% Anemic	LCI	UCI	Weighted N
Angola 2006	5.9	3.3	10.2	260
Angola 2011	3.9	2.8	5.5	1,040
Benin 2001	30.9	27.2	34.8	736
Benin 2006	23.2	20.9	25.6	1,387
Burkina Faso 2003	45.1	41.1	49.2	941
Cameroon 2004	17.3	14.9	20.0	1,083
Congo Brazzaville 2005	10.6	8.1	13.7	636
DRC 2007	15.9	12.7	19.7	1,042
Ethiopia 2005	13.0	10.4	16.0	1,225
Ghana 2003	22.0	19.2	25.1	968
Ghana 2008	25.7	22.3	29.5	717
Guinea 2005	23.9	19.8	28.5	803
Liberia 2009	7.4	5.3	10.2	1,129
Madagascar 2003-04	12.5	8.8	17.5	613
Madagascar 2008-09	4.0	3.1	5.2	1,565
Malawi 2004	22.7	19.2	26.6	759
Malawi 2010	13.7	11.5	16.1	1,490
Mali 2006	30.5	27.2	34.0	1,169
Mali 2010	32.5	27.3	38.3	548
Niger 2006	23.4	20.6	26.5	1,211
Nigeria 2010	16.4	13.8	19.5	1,410
Rwanda 2005	9.2	7.5	11.4	1,135
Rwanda 2007-08	3.1	2.3	4.1	1,659
Rwanda 2010	2.7	1.9	3.8	1,180
Senegal 2005	23.9	20.6	27.5	819
Senegal 2008-09	16.7	13.6	20.3	1,132
Sierra Leone 2008	14.8	11.8	18.5	727
Swaziland 2007	6.5	4.7	8.8	704
Tanzania 2004-05	16.9	15	19.0	2,441
Tanzania 2007-08	11.2	9.6	13.0	2,102
Tanzania 2010	8.1	6.5	10.1	2,147
Uganda 2006	27.2	23.8	30.9	760
Uganda 2009-10	17.7	14.5	21.3	1,048
Zimbabwe 2005-06	6.8	5.4	8.5	1,266
Zimbabwe 2010-2011	6.4	5.1	8.0	1,278

Appendix Table C. Proportion of last-born children age 6-23 months who reported using an ITN the night before the survey

Dataset	% Used ITN	LCI	UCI	Weighted N
Angola 2006	23.7	17.5	31.3	276
Angola 2011	33.6	29.7	37.7	1,086
Benin 2001	5.6	4.3	7.2	1,428
Benin 2006	23.5	22.0	25.1	4,566
Burkina Faso 2003	2.0	1.4	2.7	2,811
Cameroon 2004	2.1	1.3	3.4	1,135
Congo Brazzaville 2005	4.9	3.6	6.8	1,341
DRC 2007	7.2	5.4	9.5	1,147
Ethiopia 2005	1.9	1.2	3.3	1,385
Ghana 2003	5.8	4.4	7.6	1,033
Ghana 2008	33.8	29.9	38.0	826
Guinea 2005	1.0	0.5	2.1	852
Liberia 2009	32.5	28.1	37.2	1,161
Madagascar 2003-04	2.5	1.8	3.5	1,803
Madagascar 2008-09	48.7	45.6	51.9	1,690
Malawi 2004	15.8	14.0	17.8	3,278
Malawi 2010	48.2	44.9	51.5	1,652
Mali 2006	30.5	28.1	33.0	3,806
Mali 2010	75.9	70.5	80.6	571
Niger 2006	8.4	6.5	10.9	1,326
Nigeria 2010	31.1	26.6	35.8	1,608
Rwanda 2005	15.5	13.3	18.0	1,163
Rwanda 2007-08	63.1	60.1	66.1	1,696
Rwanda 2010	75.0	72.2	77.5	1,200
Senegal 2005	7.2	5.5	9.5	976
Senegal 2008-09	31.1	27.6	34.8	1,265
Sierra Leone 2008	31.7	27.9	35.9	851
Swaziland 2007	0.9	0.5	1.8	765
Tanzania 2004-05	18.1	15.6	20.9	2,485
Tanzania 2007-08	29.5	26.6	32.6	2,229
Tanzania 2010	64.8	61.8	67.8	2,278
Uganda 2006	13.0	10.2	16.5	804
Uganda 2009-10	34.9	29.8	40.3	1,059
Zimbabwe 2005-06	3.2	2.3	4.5	1,484
Zimbabwe 2010-2011	12.1	10.0	14.5	1,589

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