Published: June 2015

Prevalence and risk factors of malaria in children under the age of five years old in Uganda

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Malaria is considered one of the main global health problems causing close to a million deaths each year. Ninety percent of these deaths occur in Sub-Saharan Africa and 70% of the deaths are of children under the age of 5 years (1). Malaria is the leading cause of morbidity in Uganda with 95% of the population at risk and it kills between 70,000 and 100,000 children every year (2).

Children under the age of five years are among the most vulnerable to malaria infection as they have not yet developed any immunity to the disease. In order to apply successful interventions to eradicate malaria, there is a continuous need to understand the epidemiology and risk factors associated with the disease. There have been very few studies done in Uganda on malaria indicators and risk factors. These studies have also been specific to one community at a time (3-4). Most recent studies on malaria in Uganda have been hospital-based, investigating clinical malaria among young children and pregnant women (5-6). The Malaria Indicator Survey (MIS) in 2009 was the first nationally representative survey of malaria conducted in Uganda, and the Ministry of Health plans to carry out this survey every couple of years. The aim of the study presented here was to use this Malaria Indicator Survey to investigate the distribution of malaria infection in children under the age of 5 years old in the different regions of Uganda, as well as to investigate the relationship between the malaria status of these children and selected socio-economic, demographic and environmental factors.

Nationally representative sample

The sample was stratified into 9 survey regions of the country, plus the capital city, Kampala, which, due to it being entirely an urban district, comprised a separate region. Each of the 9 other regions consisted of 8 to 10 administrative districts of Uganda that shared similar languages and cultural characteristics. Figure 1 below shows these 10 sampling regions of the country. The sample was not spread geographically in proportion to the population, but rather equally across the regions, with 17 clusters per region. The survey consisted of a two-stage sample design where the first stage involved selecting clusters from a list of enumerations areas (EA) covered in the 2002 Population Census. A total of 170 clusters (17 clusters for each of the 10 regions) with probability proportional to size were selected. These clusters consisted of 26 urban areas and 144 rural areas. Several months before the survey took place, a list of all households in the 170 clusters was drawn up and provided the sampling frame from which the households were then selected. The second stage of the selection process involved systematic sampling of households from the list of households in each cluster. Twenty-eight households were selected in each cluster.

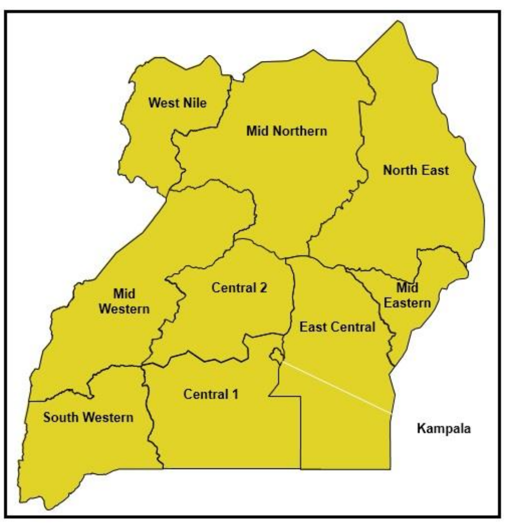

Figure 1: Map of sampling regions of Uganda

Household and Woman's questionnaire

The survey was carried out during November and December 2009 to correspond with the peak in malaria transmission. Two questionnaires were used in the MIS, a Household Questionnaire and a Woman's Questionnaire for all women aged 15 to 49 years in the sample. With the consent of a parent or guardian in the household, all children between the ages of 0 and 59 months were tested for malaria using two testing procedures; a rapid diagnostic test (RDT) and microscopy.

The RDT consisted of testing a drop of blood using the Paracheck Pf^{TM} rapid diagnostic test, which tests for the parasite *Plasmodium falciparum*, the most dangerous *Plasmodium* parasite. The result of the test was available in 15 minutes. Faint test lines were considered positive. The second test procedure involved taking two blood smears; one thick and one thin. Thick blood smears were examined for malaria infection by calculating parasite and gametocyte densities by counting the number of asexual parasites and gametocytes per 200 leukocytes. A thick blood smear was considered negative when the examination of times 100 high-power field (HPF) did not reveal asexual parasites or gametocytes. Thin blood smears were examined to determine the plasmodium infection.

Relating malaria infection to socio-economic, demographic and environmental factors

Unlike the microscopy tests, RDTs are more readily available and do not require technicians with advanced skills and laboratories. However, the RDT detects the *Plasmodium falciparum*-specific protein (not the parasite itself), which can remain in the blood for several weeks after treatment. Therefore, this test is less sensitive and often results in slightly higher rates of malaria.

Microscopy is considered the gold standard and is a highly sensitive test. Therefore, for the purpose of this study, the malaria status of a child was according to the microscopy test result. Thus, the response variable was binary, indicating whether a child tested positive or negative for malaria.

The independent variables that were considered comprised of a number of socio-economic, demographic and environmental factors. Such variables included the age and gender of the child; number of members in the household; caregiver's age, education level and knowledge of malaria; type of place of residence: rural or urban; cluster altitude and region of Uganda; main source of drinking water; type of toilet facilities; whether or not the household had electricity, a refrigerator, bicycle, television or a radio; main material of the floors, walls and roof of the household; incidence of anti-malarial spraying in the last 12 months; use of mosquito nets and total number of mosquito nets used in the household.

Statistical models for complex survey designs

Surveys carried out using sampling techniques such as multistage sampling, stratified random sampling, cluster sampling or sampling with unequal weights are often referred to as having complex survey designs. Modelling of data obtained from these surveys must take into consideration the design of the study for the following reasons:

- Observations within the same cluster or household may be correlated and thus the assumption of independence in the data cannot be met.
- Only a limited number of clusters are sampled thus leaving a significant portion of the population unsampled.
- Sample units may be selected with unequal weights or probabilities.
- Often surveys are subjected to non-response. This may result in unmeasured characteristics which could lead to biased results.

Logistic regression is commonly used to explore the relationship between a binary response variable and a set of explanatory variables. However, this method of analysis is not valid if the data come from complex survey designs (7). There are many methods of dealing with this design of the study. Two such commonly used approaches are design-based and model-based statistical methods (8). A designed-based method, which involves the extension of logistic regression to complex survey designs, is survey logistic regression, first introduced by Binder (9). For design-based methods, parameter estimates and inferences are based on the sampling weights, and only inferences concerning the effects of certain covariates on the response variable are of interest.

However, model-based methods are used when interest is also on estimating the proportion of variation in the response variable that is attributable to each of the multiple levels of sampling (10). In this case, inference on the variance components of the model may also be of interest and calculations of the model's parameter estimates do not utilize the sampling weights.

Such model-methods include generalized linear mixed models (GLMM) and generalized estimating equations (GEEs). All three of these methods (survey logistic regression, GLMM and GEEs) were applied to the MIS data, however, they produced similar results.

Lower socio-economic status associated with a higher risk of malaria.

A total of 3,972 children were tested for malaria. Of those children, 1,725 tested positive, resulting in an observed prevalence of 43.4%. All three models found the child's age in months; the caregiver's education level; region of Uganda; cluster altitude; type of place of residence; availability of electricity in the household; source of drinking water; main floor and wall material; and the number of mosquito nets in the household to be significantly associated with a child's malaria status.

Being older was associated with a slightly higher risk of malaria. However, a child's risk of malaria decreased with an increase in cluster altitude and as the number of mosquito nets in the household increased. Compared to children with caregivers who had a secondary education, those with caregivers who had no education were most at risk for malaria, followed by those with caregivers who had only primary education. A child's risk of malaria was substantially greater in rural areas than in urban areas. Children in households with access to clean and safe drinking water were more likely to test negative for malaria. Children residing in the East Central region of Uganda had the highest risk of malaria, followed by those in the Central 2 and Mid Eastern regions. Poor housing construction was associated with a higher risk of malaria.
Furthermore, children in households with no electricity had a higher risk of malaria.

The results of this study largely agreed with those in the literature, where a lower socio-economic status was associated with a higher risk of malaria. The study revealed a great lack of knowledge of the causes of malaria, as well as possible ways of avoiding it. Mosquito net usage and incidence of indoor residual spraying were very low. Although the government of Uganda has adopted various strategies for malaria control, there is still a long way to go before a significant reduction in malaria can be seen. The extent of the under-development of the country presents a great challenge in the efforts of malaria reduction, especially as poor housing conditions are experienced by a vast majority of the population. As resources for malaria control in Uganda are very limited, and the different regions of the country have been shown to be unequally at risk, it is of great importance to identify the geographical areas that are most at risk using updated malaria risk maps. Risk maps, created through spatial modelling, have been recognized as an important tool for malaria control where they can effectively guide the allocation of the limited resources and interventions.

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