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Joint modeling of Anaemia and Malaria in children under five in Nigeria

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ABSTRACT

Malaria and anaemia which jointly account for high proportion of morbidity and mortality among young children in developing countries have been individually studied using binary regression model. We adopt geoadditive latent variable model for binary/ordinal indicators to analyze the influence of variables of different types on the morbidity among young children in Nigeria. Latent variable models allow for the analysis of multidimensional response variables that reveal the indicator's underlying relationship that are caused by the latent variables. We extend the structural model to a semi-parametric geoadditive model in order to quantify the joint spatial structure of morbidity from malaria and anaemia. Findings revealed substantial geographical variations and the generated maps can guide policy makers and donors on how to prudently utilize the scarce resources for designing more cost-effective interventions.

1. Introduction

Notwithstanding the various intervention programmes by government and donor agencies, young children from most developing countries have continued to suffer morbidity and mortality from malaria, anaemia and other infectious diseases. The scourge of these preventable diseases is enormous with wanton socio-economic effects on the populace. Globally, more than 300 million clinical cases and over 2 million fatalities result from malaria annually (WHO, 2008). In Africa, up to 25% of the malarial disease burden come from Nigeria where more than 60% of outpatient visits and 30% admissions are prompted by malaria symptoms hence, the country contributes significantly to the over a million lives lost per year in the region, which mostly consists of young children and pregnant women (Federal Ministry of Health, 2011; NPC, NMCP and ICF International, 2012). Pungent evidence exists to effectively demonstrate the remarkable synergy between the epidemiological causal pathways of malaria and anaemia. Compared with other parasites, Plasmodium falciparum can invade the larger percentage of red blood cell (RBC) leading to acute and chronic hemolysis and disordered red cell development leading to severe anaemia (Caulfield et al., 2004). This makes anaemia one of the complications usually noticed in malaria infections and it contributes to its morbidity and mortality. On the other hand, severe anaemia exacerbates malaria in endemic regions, and is also associated with hookworm and bacteremia (Calis et al., 2008, Ekvall, 2003). Over half of malaria attributed mortality is ascribed to severe anaemia. (White, 2004, Murphy and Breman, 2001).

The triumph of any healthcare intervention programme largely depends on a comprehensive and accurate understanding of the multifaceted factors that determine the

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occurrence of diseases and death. Until lately, available information on the occurrence of malaria, anaemia and other childhood diseases in Nigeria has been based on data from clinics and hospitals. However, information obtained from hospitals are only a small fraction of all cases because there is evidence that many care givers are so well aware of the signs of fever associated with malaria that 80% of fevers are managed at homes (Akogun, 2008, Kazembe et al., 2007 and Kofoed et al., 2004). To this end, hospital records may not be suitable for estimating the prevalence and risk factors of malaria and other infectious diseases for proper programme development. As a substitute, the cross-sectional survey conducted by the Demographic and Health Survey Program, under the Malaria Indicator Survey has collected information on malaria and anaemia among children under five years of age. This was made possible through the on-the-spot testing for malaria using the rapid diagnostic test and the use of battery-operated HemoCue analyzers for haemoglobin testing thereby providing a nationally representative sample that allows for accurate estimation of the prevalence as well as other information necessary for estimating the risk factors and detailed geographical distribution.

In this study, we adopt the geoadditive latent variable model (geoLVM) for binary and ordinal indicators (Raach, 2006) to analyze the influence of variables of different types on morbidity from malaria and anaemia among young children in Nigeria. Latent variable models allow for the analysis of multidimensional response variables in such a manner that reveal the indicator's underlying relationship that are caused by the latent variables. The model extends the classical factor analysis by allowing for variables beyond the Gaussian manifest variables, as common in many areas of applications. LVM can be classified into three groups: the LVM without covariates, the LVM with covariates and the structural equation modeling. While the latter extends standard LVM by relating the latent variables to each other, the LVM with covariates is a natural extension of LVM without covariates, in which observed covariates can modify the indicators or the latent variables in the manner of standard parametric regression. The model allows for latent dependent variables and explanatory variables to be examined. In this case study, the structural model was extended to a semi-parametric geoadditive regression that allows for modeling of linear and nonlinear covariate effects while accounting for location-specific contextual factors through geographical effects. Shared component model is an alternative model that can be utilized in measuring joint spatial effects in disease mapping.

The data for the case study is presented in Section 2, while Section 3 presents the modeling technique. Data analysis, results and discussion of the findings are presented in Section 3.3.

2. Data

The 2010 Nigeria Malaria Indicator Survey aimed at collecting information on malaria indicators in addition to malaria and anaemia prevalence. This was the first of its kind to collect such information nationally. The survey, commissioned by the National Malaria Control Programme was implemented by the National Population Commission and other Roll Back Malaria partners. It was carried out from October to December, 2010. Whereas all women aged 15–49 years in the selected households were eligible for individual interviews, all children aged 6–59 months in the sampled households were eligible to be tested for anaemia and malaria. After obtaining informed consent of the parents/guardians of the children, blood samples were collected using a microcuvette to obtain a drop of blood from a finger prick (or a heel prick in the case of young children with small fingers) to perform on-the-spot testing for malaria and anaemia, and to prepare the smears and films that were read in the Department of Medical Microbiology and Parasitology laboratory at the University of Lagos to determine the presence of malaria parasitaemia. The rapid diagnostic testing using Paracheck Pf test which tests for *P. falciparum* was used for on-the-spot malaria testing. The test includes a loop applicator that comes in a sterile packet. A tiny portion of blood is captured on the applicator and placed in the well of the device, which produces results in about 15 min. The prepared blood smears and films were then fixed with analar methanor. The field teams, which included one laboratory scientist carefully package the slides in sturdy slide boxes for transportation to the laboratory. Giemsa staining of the slides was carried out at the laboratory, and the presence and species of malaria parasite determined by microscopic examination. Haemoglobin analysis was done on site using a battery-operated portable HemoCue analyzer, which produces result within a minute.

A two-stage probability sampling was adopted for the survey. The sampling frame used for the 2006 Population and Housing Census of the Federal Republic of Nigeria was made use of to select, at the first stage, the primary sampling unit (clusters) on the basis of enumeration areas defined for the census frame. This comprises of 83 in the urban areas and 157 in the rural areas making 240 clusters but the final sample included 239 clusters as access to one was not possible due to inter-communal disturbance. A complete listing of households was conducted within each state (Nigeria comprises of 36 states and a Federal Capital Territory), and a mapping exercise of each cluster was carried out from August through September 2010. At the second stage, an average of 26 households was selected in each cluster by equal probability sampling. A total of 6197 households were selected, and of these, 5986 were occupied as at the time data collection. Of the occupied households, 5895 were successfully interviewed, yielding a response rate of 99%. The holistic advocacy approach that include sensitization programmes through the use of mass media, engagement of the community and religion leaders contributes significantly to the huge success and high response rate of the survey. Additional information collected from the households and explored in this study includes: sex of the child, mother's educational attainment, household wealth index, type of place of residence, ethnicity, ownership and use of bed net, number of rooms for sleeping, type of roofing material of the dwelling, and whether or not the child has fever. The children's fever status was determined by the field teams by means of measuring axillary body temperature. A temperature of 37.58 Celsius or