Unravelling the Effects of Neighbourhood Contextual Influences on Childhood Mortality and Morbidity in Nigeria

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DEDICATION

This thesis is dedicated to God Almighty.

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SUBMISSION DECLARATION

I declare that the submitted material as a whole is not substantially the same as published or unpublished material that I have previously submitted, or am currently submitting, for a degree, diploma, or similar qualification at any university or similar institution. No parts of the works have been submitted previously for any aforementioned qualification.

ABSTRACT

Background: The burden of childhood stunting and mortality remains huge in developing countries and in particular in the Sub-Saharan Africa region to which Nigeria is located. Despite the body of evidence supporting an association between neighbourhood contextual influences and health outcomes, few studies have examined the relationship between neighbourhood-level risk factors and childhood undernutrition (stunting) and mortality independent of the individual-level risk factors in a single analytical framework in Nigeria. Most studies to date have focused on individual-level factors overlooking the contribution of neighbourhood or area level factors. Beyond the effect of neighbourhood contextual influences, a child's health will be influenced by the state, region and national policies and programs that in turn will affect the proximate determinants of his or her survival and health status.

Aims: We described the variation that existed between the states in Nigeria using league table, control chart and spatial clustering of childhood stunting (Study I) and examined the contribution of community contextual factors at predicting childhood stunting beyond individual-level factors (Study II). We further identified and examined the predictors of childhood mortality in Nigeria (Study III) and developed prognostic model predicting differences in childhood mortality in Nigeria communities (Study IV). We also quantified the contribution of neighbourhood socioeconomic disadvantage alongside individual-level socioeconomic status to childhood mortality in Nigeria using multilevel analysis (Study V).

Methods: We used the Nigeria Demographic and Health Survey (DHS) dataset which comprised of 28,647 and 31,482 under-five children nested within 888 and 896 communities for the 2008 and 2013 surveys respectively from 37 states including the Federal Capital Territory.

We used league table, control chart and geospatial analysis to describe variations in childhood stunting that existed between the states in Nigeria (Study I). In study II, we applied multivariable multilevel logistic regression analysis to describe the independent contribution of community contextual influences (factors) alongside the individual level factors on childhood stunting in Nigeria. We applied multivariable logistic regression analysis that included Receiver Operating Characteristics (ROC) Curve to construct a model that examined the factors associated with childhood mortality (Study III). In study IV, we used mixed multivariable Poisson regression analysis to develop a prognostic model predicting differences in childhood mortality in Nigeria communities. In Study V, we applied multivariable multilevel logistic regression analysis and considered three measures of individual socioeconomic status i.e. maternal educational attainment, household wealth status, and employment status of the mothers. At the neighbourhood (level 2) and state (level 3), we included poverty rate, unemployment rate, and illiteracy rate.

Results: There were statistically significant variations in the odds of childhood stunting and mortality across the neighbourhoods (Study II, IV & V) and states (I) in Nigeria. This confirmed the evidence of community and state level contextual phenomenon influencing childhood survival and stunting. Children residing in socioeconomically disadvantaged neighbourhoods had higher odds of childhood morbidity and mortality compared to their counterparts living in more socioeconomically advantageous neighbourhoods (Study II, IV & V). The odds of childhood morbidity and mortality were associated with neighbourhood and state socioecological conditions even after adjusting for individual's household socioecological conditions (Study II, III, IV & V). There was moderate positive correlation between neighbourhood and individual variations in childhood mortality and morbidity (Study II & V).

The odds of childhood stunting and mortality were higher in children residing in rural areas (Study II, III, IV & V) and in settings with poor sanitation (Study III & IV). Other factors that increased the odds of childhood mortality included low level of maternal health seeking behaviour, not breastfed for >18 months, being from a polygamous family setting, large family and high birth order, non-usage of contraceptive by mother, and mother having first marriage during their teenage years(Study III). Good household wealth status, adequate birth interval, being a female child and having normal birth weight, increasing maternal educational attainment were all associated with odds of not suffering from childhood stunting and surviving beyond five years of age (Study II & V).

Conclusions: By adopting several modelling approaches including the multilevel modelling, we added to the growing body of evidence the effects of the neighbourhood contextual influences on childhood stunting and survival in Nigeria. Our study revealed that individual i.e. children and parental factors; neighbourhood and socioecological environment were associated with childhood stunting and mortality. Efforts at reducing the burden of childhood stunting and mortality should be directed at establishment of poverty alleviation programmes, effective publicly funded health care delivery, promotion of hygienic environmental practices and health education more importantly at the neighbourhood level. Lastly, given the importance of socioecological factors at influencing the lifestyles of neighbourhoods and individuals, interventions targeting structural make up of these two entities are vital in order to meet the MDGs 1 and 4 regarding childhood stunting and mortality in Nigeria and in particular developing countries in general.

LIST OF PUBLICATIONS

I. **Adekanmbi V T,** Uthman O A, Mudasiru O M. Exploring variations in childhood stunting in Nigeria using league table, control chart and spatial analysis. *BMC public health* 2013; 13:361.

II. **Adekanmbi V T,** Kayode G A, Uthman O A. Individual and contextual factors associated with childhood stunting in Nigeria: a multilevel analysis. *Maternal & child nutrition* 2013; 9:244 - 59.

III. Kayode G A, **Adekanmbi V T,** Uthman O A. Risk factors and a predictive model for under-five mortality in Nigeria: evidence from Nigeria demographic and health survey. *BMC pregnancy and childbirth* 2012; 12:10.

IV. **Adekanmbi V T,** Kandala N B, Stranges S, Uthman O A. Factors that predict differences in childhood mortality in Nigerian communities: a prognostic model. *Journal of Paediatrics 2015; DOI:10.1016/j.jpeds.2015.09.057*

V. **Adekanmbi V T,** Kandala N B, Stranges S, Uthman O A. Contextual socioeconomic factors associated with childhood mortality in Nigeria: a multilevel analysis. *Journal of Epidemiology & Community Health* 2015; 69:1102- 08.

LIST OF ABBREVIATIONS

CI	Confidence Interval
CrI	Credible Interval
DIC	Deviance Information Criterion
DHS	Demographic and Health Survey
ESDA	Exploratory Spatial Data Analysis
FMOH	Federal Ministry of Health
ICC	Intra-Class Correlation
IRB	Institutional Review Board
HAZ	Height for Age Z-score
LISA	Local Indicator of Spatial Association
LMIC	Low and Middle Income Countries
MCMC	Markov Chain Monte Carlo
MDGs	Millennium Development Goals
MHSBI	Maternal Health Seeking Behavioural Index
MOR	Median Odds Ratio
NHREC	Nigeria Health Research Ethics Committee
OR	Odds Ratio
PCA	Principal Component Analysis
PCV	Proportion Change in Variance
ROC	Receiver Operating Characteristics
RR	Relative Risk
SES	Socio-Economic Status
SED	Socio-Economic Disadvantage
UFMR	Under-Five Mortality Rate
UN	United Nations
UNDP	United Nations Development Programme
VPC	Variance Partition Coefficient
WHO	World Health Organization

AN OVERVIEW OF THE FIVE STUDIES

Study	Short title	Data source	Study design	Outcome	Statistical method	Level of analysis
Study I	Variations in childhood stunting	Nigeria DHS 2008	Cross-sectional	Childhood stunting	League table, control chart and spatial analysis	State
Study II	Individual and contextual factors	Nigeria DHS 2008	Cross-sectional	Childhood stunting	Multilevel logistic regression	Individual and neighbourhood
Study III	Risk factors and predictive model	Nigeria DHS 2008	Cross-sectional	Under-five mortality	Multivariable logistic regression	Individual, household and community
Study IV	Predicting differences in childhood mortality	Nigeria DHS 2013	Cross-sectional	Under-five mortality	Mixed multivariable Poisson regression	Community
Study V	Contextual socioeconomic factors	Nigeria DHS 2013	Cross-sectional	Under-five mortality	Multilevel logistic regression	Individual, neighbourhood and state

INTRODUCTION

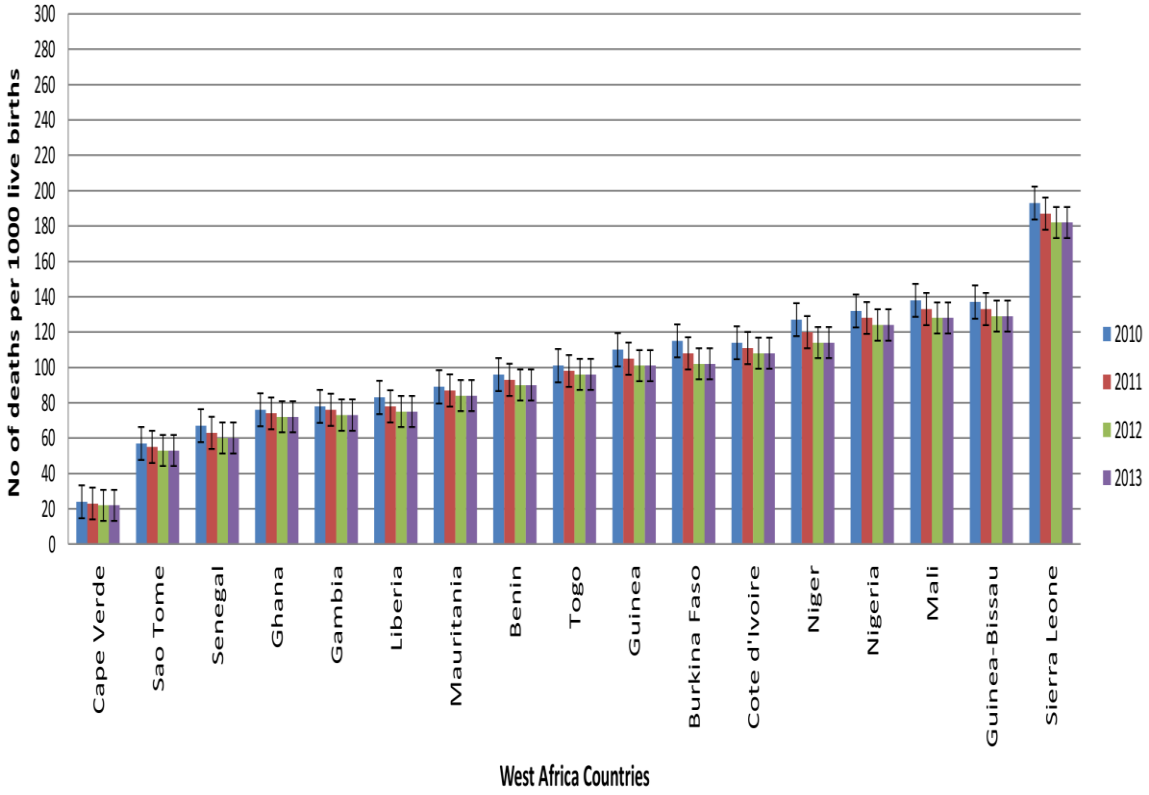
Burden of childhood morbidity and mortality

Childhood mortality has continued to be a major public health concern worldwide but more importantly in low and middle income countries (LMICs) where it is mostly concentrated and keeps occurring in large numbers. Available data from World Health Organisation (WHO) estimate childhood mortality to be about 9 million deaths per year in which 70% of the deaths are avoidable making it an important public health problem warranting further exploration and study.(1) Childhood mortality has once been described as public-health calamity in the first of the series of articles on child survival published in the Lancet journal.(2) Due to the heavy burden of childhood mortality globally and more importantly in the developing world, the United Nation (UN) incorporated reduction of childhood mortality by two-thirds by the year 2015 from the baseline in 1990 as its fourth and most ambitious of the eight Millennium Development Goals (MDGs).

Under five mortality rate (UFMR) used interchangeably as childhood mortality rate in this study in Nigeria has been estimated to be about 159 deaths per 1000 live births in a research carried out jointly by World bank/World Health Organisation in 2005. Their latest estimates done in 2013 showed a slight decline to about 120 deaths per 1000 live births.(3) This decline is still out of line with the international acceptable standard of 60 deaths per 1000 live births for the LMICs.(3) Another large scale study conducted by Rajaratnam and colleagues between 1970 and 2010 in about 187 countries showed that childhood mortality rate in Nigeria in year 2010 was 157 deaths per 1000 live births.(4) Currently available data from the United Nations Development Programme (UNDP) indicate that Nigeria alone accounts for approximately 10% in the burden of childhood mortality in West Africa sub-region.(5)

Figures 1 below shows the trend in UFMR in Nigeria compared to other countries in West Africa as a whole. UFMR in Nigeria as of now is estimated to be about 124 deaths per 1000 live births.(5) Looking at the above statistics clearly reveals that childhood mortality remains a major public health issue in Nigeria that needs to be solved.

Figure 1: Under five mortality trends between 2010 and 2013 in West Africa (Adapted from United Nations Development Programme (2014) (5)



In the 1990s, both Pelletier(6) and Schroeder(7) and their colleagues established the contribution and association of malnutrition in the form of under nutrition to childhood mortality. Their analytical framework took the underlying cause of deaths into account and they inferred that under nutrition measured as poor anthropometric status was an associated cause of death in about half of all childhood deaths occurring in the developing countries.

A recent study conducted by Black et al published in the Lancet journal also concluded that under nutrition in the aggregate—including fetal growth restriction, stunting, wasting, and deficiencies of vitamin A and zinc along with suboptimum breastfeeding—was a cause of estimated 3·1 million child deaths annually or 45% of all child deaths recorded in 2011.(8)

Stunting used interchangeably as morbidity in this study is a form of under-nutrition whereby there is restriction to the linear development and growth of an individual which may occur during prenatal and postnatal periods of life as a result of infections, inadequate and/or poor nutrition and adverse environmental conditions.(9-11) Stunted growth that occurs early in life may lead to poor cognition, socio-psychological and motor development with higher probability of occurrence of childhood mortality.(12;13) Children suffering from stunting are unable to reach their full growth potentials and often become stunted adolescents and adults later on.(14) Functional difficulties resulting in reduced work capacity and efficiency are often the consequences of stunting if it persists into adulthood period.(15) There is increased risk of morbidity and mortality during the intra-partum period for both women with stunted growth and their babies.(16-18)

Childhood stunting globally has been estimated to be present in about one-third of preschool children in a large scale research conducted by the WHO in year 2004.(19) Despite the fact that the worldwide prevalence of childhood stunting is on the downward trend from about 47% in 1980 to about 35% in 2004, there are variations in the prevalence depending on geographic regions being investigated.(19)

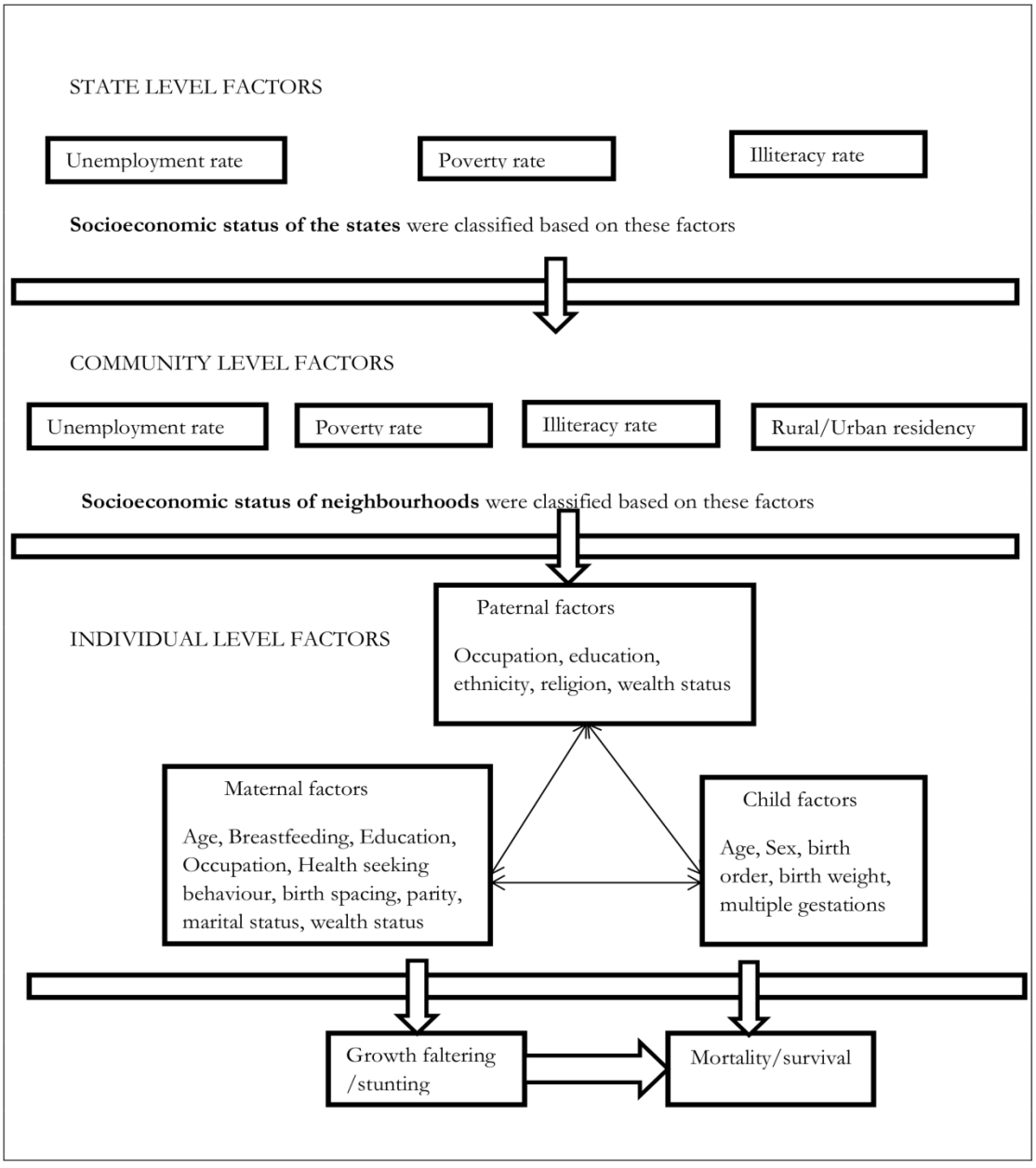
Furthermore, the progress that has been achieved at reducing the burden of stunting in the developing world which is the most affected part of the globe has been in the Southeast Asia with insignificant progress in the Sub-Saharan African region.(20) Similarly, a study conducted by WHO in Nigeria in 1990 estimated the prevalence of childhood stunting to be about 43.1% (21) while in 2008 and 2013, the Nigeria DHS carried out showed that 41% and 39% of the under-fives have stunted growth.(22;23) Looking at the statistics presented by the above studies clearly show that childhood stunting in Nigeria remains a major problem that needs to be solved.

Conceptual framework /Theoretical models

Drawing largely upon the conceptual framework developed by Mosley and Chen (24), this research adapted and developed a working conceptual framework that aided in the choice of variables with which we explored the factors associated with child morbidity and mortality in Nigeria**.** The theoretical model developed by Sastry(25) served as the framework for explaining the clustering effect/variation in childhood morbidity and mortality observed at various levels of operation (i.e. individual/household, neighbourhood and state levels). Hence, the association between individual and contextual predictors of childhood morbidity and mortality in this study was conceptualized based on the foundation laid by the two theoretical frameworks.

Childhood survival researchers in the developing countries often draw upon socioecological theory as postulated by Mosley et al (1984) to understand the causes of mortality and morbidity in the childhood period **(Figure 2)**. (24;26)

Figure 2: Socioecological conceptual framework for determinants of child survival in developing countries (Adapted from Mosley and Chen (1984))(24)



This model conceptualizes childhood survival as multifaceted process based on the interplay of individual, household, neighbourhood and societal factors.(26) The model takes into account the different levels of social environment and their roles in influencing childhood morbidity and mortality.

A child resides in a household, which on the other hand is sited within a neighbourhood, which will operate under the policies of a state which in turn operates under a regional or national government. Socioecological model has been used extensively by researchers to understand the interplay of individual, circumstances and socio-cultural factors that come together to cause childhood morbidity and mortality.(24;26) This framework postulates that childhood morbidity and mortality arise from the interplay of factors at different levels of the social environment. Socioecological model allows for the inclusion of potential risk factors from different domains of influence such as individual, family, neighbourhood and societal levels. Building such a model also allows for a fundamental structure for understanding the interplay of all the factors that influence childhood morbidity and mortality, and can therefore provide key areas for prevention as well as solution and intervention. This framework also provides the theoretical basis to a comprehensive public health approach that not only addresses an individual's risk of dying but also the belief's, culture, norms and socioeconomic processes that cause the situation leading to childhood morbidity and mortality.

Frailty model and random effects concept

We adopted the concept of frailty effect from the works of Clayton,(27) Vaupel et al(28) and Sastry(25) which in this study refers to a child's predisposition to the risk of dying or suffering from childhood morbidity.

According to Sastry, this model captures the total effects of all factors that influence the child's likelihood of dying or becoming stunted that are not captured in the model that accounts for the measures of association. Because measures of association model can

account for the observed predictors, the frailty effects stand for unobserved/unmeasured or unmeasurable effects.

If no predictor variables are included in the model i.e. an empty or null model then the estimated frailty distribution characterizes the extent of clustering of child mortality and morbidity risks in the study population; in our study, the frailty effects encompasses the total effect of all observed and unobserved factors associated with childhood morbidity and mortality, after adjusting for the predictor and control variables. The specific factors that comprise the frailty effect clearly depend on the specific application and on the completeness of the set of observed predictor variables. In the context of our study focusing on childhood mortality and morbidity, and with special focus on the effects of unobserved factors leading to childhood mortality and morbidity, the frailty effect reflects an array of factors that can be broadly classified as behavioural, environmental and genetics.(25) Our framework for interpreting frailty effects was organized around these three sets of factors **(see Figure 3)**.

Figure 3: Frailty effects framework for interpreting random variation on child survival based on the level of operation and the form of the effect (Adapted from Sastry (1997))(25)

Level of operation	Form of effect: Genetic	Behavioural	Environmental
Child	Idiosyncratic genetic factors	Child-specific behaviour and care	
Family	Genetic factors shared among all siblings	Parental competences, care of children common to all siblings	Household environment
Community		Shared preferences, values, and cultural influences	Infrastructure, climate, physical and disease environment
State		Shared preferences, values, cultural and political influences	Infrastructure, climate, physical and disease environment at the state level

Rationale for this study

The study of childhood mortality and morbidity in a holistic way has become feasible in most developing countries and in particular in Nigeria owing to the availability of a nationally representative datasets on various maternal and child health indicators collected by DHS program in conjunction with National Statistical office based on robust sampling techniques.

There are several studies that have been carried out to examine the determinants of the factors associated with childhood mortality in Nigeria. Nevertheless, majority of them have only focused on individual-level factors (maternal and child) without adjusting for contextual (area - neighbourhood and state) level factors.(29-32). It is worthy to note that the association between contextual factors and health outcomes have been widely documented in the literature.(33-37)

Survival of a child is beyond individual level (maternal and child) factors alone, it can also be influenced by household, neighbourhood and societal factors. Furthermore, carrying out studies that concentrate only at one level - micro or contextual-level can result to practical and methodological quagmire. For example, studies that focus more on individual-level factors only are susceptible to individualistic (atomistic) fallacy.(38;39) This is because association at individual level might be different from association at group or area-level. Correspondingly, studies conducted at group or area-level alone are susceptible to ecological fallacy otherwise known as fallacy of division.(38-40)

Various studies conducted globally and particularly in the developing world have also revealed that childhood stunting is associated with socioeconomic factors such as poverty and illiteracy.(41-44) Access to quality healthcare services and maternal health seeking behaviour were also found to be important in determining nutritional status of children in some studies. This is because children that had no or less access to quality healthcare services were more prone to childhood stunting.(44-46) Poor sanitary and environmental conditions have also been linked with childhood stunting in a couple of studies.(47;48) There is a paucity of literature on childhood stunting in Nigeria and the few ones that have been published examined either socioeconomic,(49) cultural,(50) environmental, individual, or community risk factors alone. Therefore, effects of confounders were not sufficiently explored.

Most studies conducted to date in Nigeria on children's nutritional status have been conducted in urban areas with few studies in the rural areas (50-55) where approximately 70% of the population resides. Thus, contextual influences on childhood survival and stunting need to be explored further to understand a more complete process.

Public Health importance

Understanding relative contribution of individual, household and area level factors at predicting childhood mortality and stunting is important for policy makers in deciding priority areas for intervention particularly crucial for disadvantaged communities in Nigeria.

AIM AND OBJECTIVES

Overall aim

The overarching aim of this PhD project is to establish the extent to which neighbourhood/community contextual influences predict childhood mortality and morbidity (stunting) beyond individual-level risk factors with a view to provide reliable and accurate information for policymaking and program design aim at addressing the determinants of childhood mortality and morbidity in Nigeria. This aim will allow us to further explore and draw attention to the effects of the numerous and unexplored/under-explored body of contextual risk factors. It would further assist us to adjust for some portion of the variance that cannot be explained by the traditional individual-level risk factors.

Specific objectives:

- To determine and describe the variation between states in Nigeria using league table, control chart and spatial clustering of childhood stunting (**STUDY I**)
- To examine whether neighbourhood contextual factors predict childhood stunting beyond individual-level factors (**STUDY II**)
- To identify and determine the predictors of childhood mortality in Nigeria (**STUDY III**)
- To develop prognostic model predicting differences in childhood mortality in Nigeria communities (**STUDY IV**)
- To quantify and compare the contribution of neighbourhood socioeconomic disadvantage to childhood mortality in Nigeria using multilevel analysis (**STUDY V**)

METHODS

Data sources

This research used the 2013 Nigeria DHS which is the most recent nationally representative dataset available from the Nigeria DHS for studies IV & V conducted in years 2014 and 2015 as well as the 2008 Nigeria DHS dataset for studies I, II & III which were conducted in years 2012 and 2013. The sampling procedure adopted in the Nigeria DHS has been published somewhere else. (22;23) In a nutshell, a multistage (three-stage) cluster sampling methodology was used. The country was stratified into 37 districts i.e. the 36 states plus the Federal Capital Territory (FCT). The 2006 housing and population census enumeration areas (EAs) were used as the primary sampling unit (PSU). About 888 and 896 clusters (PSUs) were selected for 2008 and 2013 respectively with probability proportional to size, that is, size is the number of households in the PSU. In the second stage, systematic sampling of the households from the randomly selected PSUs was done. A total of 36, 800 and 40, 680 households for 2008 and 2013 surveys were randomly sampled. Lastly, allocation of the households in each district in a proportional way was done among its rural and urban areas.

Overview of statistical analyses

The analytical approach included descriptive as well as bivariate and multivariate analyses. Choice of statistical methodology varied depending on the data distribution and specific study hypothesis as discussed below under each specific study. Statistical analysis included: chi-square test, control charts, spatial analysis, multivariable logistic regression that included the use of receiver operating characteristics (ROC) curve, trend analysis and multilevel regression analysis and Poisson regression. Regression diagnostics was used to judge the goodness-of-fit of the models.

Ethical Considerations

This thesis was based on secondary analysis of existing survey datasets from the archive of the DHS who granted us permission for its usage after all the identifying information has been removed. The instruments and conduct of the surveys in both 2008 and 2013 was approved by the Institutional Review Board (IRB) of ICF Macro International in the United States and Nigeria Health Research Ethics Committee (NHREC) of the Federal Ministry of Health (FMOH).

Main outcomes

Childhood mortality - Each participant interviewed was asked to provide a complete history of all her live births in chronological order. The details required include; date of birth, gender of the child at birth, number of births (single or multiple), survival status of the child, age of the child on the date of interview if the child was still alive, and age at death if the child was not alive. A synthetic cohort life table and the data of birth history were used to compute childhood mortality rate, defined as the likelihood of a child dying before reaching five years of age i.e. 0-59 months (usually expressed as deaths per 1000 live births)

Childhood stunting - childhood stunting was defined as height for age z-score less than -2 standard deviations (HAZ <-2 SD) from the median of the reference population of World Health Organization.(56;57) It is a key indicator of skeletal growth restriction resulting from chronic under-nutrition.

Independent variables

The selection of the independent variables in this body of work was based on previous literatures that have examined the risk factors associated with childhood mortality and morbidity in developing countries. We used community interchangeably as neighbourhood in this study. Full description of this community has been done elsewhere.(58) Description of the independent variables is as shown in Table 1 below

Table 1: Independent variables

Independent variables	Description
Individual level factors	
Age of child in months	Categorized into (1) 0-11, (2) 12-23, (3) 24-35, (4) 36-47, (5) 48-59
Sex of child	Categorized into (1) female, (2) male
Birth weight (grams)	Categorized into (1) low <2500 (2) normal≥2500
Type of birth	Categorized into (1) Single, (2) Multiple birth
Maternal/Household factors	
Maternal age in years	Categorized into (1) 15-24, (2) 25-34,or (3) 35-49
Educational level of mother	Categorized into (1) No formal education, (2) primary (3) Secondary or (4) Higher
Breastfeeding in months	Categorized into (1) < 6, (2) 6-12, (3) 13-24, or (4) >24
Immunisation	Categorized into (1) Incomplete (2) Complete
Occupation	Categorized into (1) Not working, (2) Manual or (3) White collar
Birth Interval	Categorized into (1) ≥24 months, (2) <24 months
Numbers of under-fives	Categorized into (1) 1, (2) 2 (3) 3, or (4) ≥4
Ethnicity	Categorized into (1) major, (2) minor
Maternal health seeking behaviour	Categorized into (1) (1st quantile) (Least), (2) (2nd quantile), (3) (3rd quantile), (4) (4th quantile) or (5) (5th quantile) (Highest)
Type of family	Categorized into (1)monogamous or (2) polygamous
Head of household	Categorized into (1) male, or (2) female
Wealth Index	Categorized into (1) (1st quintile) (Poorest), (2) (2nd quintile), (3)(3rd quintile), (4) (4th quintile) or (5) (5th quintile) (Richest)
Area/State level factors	
Community childhood deprivation index	Categorized into (1) Low , (2) High

Independent variables	Description
Community maternal socioeconomic deprivation index	Categorized into (1) Low , (2) High
Community environmental factor index	Categorized into (1) Low , (2) High
Community maternal health-seeking index	Categorized into (1) Low , (2) High
Ethnicity diversity index	Categorized into (1) Low , (2) High
Residence	Categorized into (1) rural, or (2) urban
Geographic region	Categorized into (1) North Central, (2) North East, (3) North West, (4) South East, (5) South South, or (6) South West
Poverty rate	Proportion of households living below poverty level (wealth index below 20%, poorest quintile). Categorized into (1) Low, or (2) High. Median value serves as the reference for the low and high groups.
Illiteracy rate	Proportion of people in the community with no formal education. Categorized into (1) Low, or (2) High. Median value serves as the reference for the low and high groups.
Unemployment rate	Proportion of people who are unemployed in the communities Categorized into (1) Low, or (2) High. Median value serves as the reference for the low and high groups.
Proper sanitation	Categorized into (1) Yes, or (2) No
Safe water	Categorized into (1) Yes, or (2) No

SUMMARY OF STUDIES

STUDY I

Title: Exploring variations in childhood stunting in Nigeria using league table, control chart and spatial analysis

Objective: To examine and describe the variations existing between states in Nigeria using league table, control chart and spatial clustering of childhood stunting.

Methods: The percentage of observed childhood stunting with 95% CI for each state in the country was estimated, described and plotted in rank order. The uncertainty linked to using ranks for assessing performance was then estimated by adopting simulation technique (A Monte Carlo Procedure) illustrated by Marshall EC and Spiegelhalter.(59)

We used scatter plots to examine the performance of each state as a proportion versus the number of children under five years who had stunted growth i.e. denominator for the proportion. Mean performance of the states with its exact binomial 3 sigma limits was estimated for all possible values of under-five children that were stunted in all the states, from which funnel plot was generated with the aid of procedure developed and described by Spiegelhalter.(60;61)

Lastly, we did exploratory spatial data analysis (ESDA); local measures of spatial correlation that gives a measure of correlation for each unit which in turn assists in the recognition of the specific type of spatial association that exists — ESDA was carried out with the aid of Local Indicators of Spatial Association (LISA).(62;63) Local Moran's I depicts the presence of significant local spatial correlation. A Monte Carlo Randomization (MCR) technique was adopted to re-estimate the local Moran statistics following the calculation of the appropriate statistics from the smoothed rates.

Thereafter, we generated a reference distribution based on 999 permutations from the randomized data observations.(62;63) The significance level of local spatial patterns was set at p-value of .001 which was calculated and generated by correlating the observed statistics to the distribution generated by the MCR process.(62;63)

Results: The prevalence of childhood stunting was about 39% from this study which shows that childhood stunting is high in Nigeria when compare to the global average of about 26%.(64) However, there are significant variations in the proportion of childhood stunting across the 37 states in the country including the Federal Capital Territory (FCT). The proportion of under-fives with stunted growth ranged from approximately 12% in Anambra state to 60% in Kebbi State. Ranking of states with respect to childhood stunting from the forest plot is as follows: Anambra and Lagos states had the best performances with 11.5%; 95% CI (08.2% - 14.9%) and 16.8%; 95CI (13.7 - 19.9%) respectively. Conversely, Yobe with 51.2%; 95% CI (47.5% - 54.8%), Zamfara with 51.2%; 95% CI (46.8% - 55.6%), Katsina with 54.3%; 95% CI (50.8% - 57.9%), Plateau with 55.6%; 95% CI (51.3% - 59.8%), and Kebbi with 59.7%; 95% CI (54.8% - 64.6%) had the worst performances with more than 50% childhood stunting prevalence. The control chart in figure 2 of study I showed that about 13 states in orange colour had higher than national average prevalence of childhood stunting while ESDA from figure 3 of study I identified eleven states in red colour as hot spots of childhood stunting.

STUDY II:

Title: Individual and contextual factors associated with childhood stunting in Nigeria: a multilevel analysis

Objective: To examine whether neighbourhood level factors predict childhood stunting beyond individual-level factors.

Method: Multilevel logistic regression was used to study the association between individual- and neighbourhood-level factors and childhood stunting. A multi-level modelling technique was used (65-67) to identify clustering of childhood stunting within households and neighbourhoods in Nigeria. A two-level multilevel model for binary response for childhood stunting *y* (with y = 1, if the child was stunted) was specified. The levels include individual (level 1) and neighbourhood (level 2). The result of (*Fixed effects - measures of association*) was shown as odds ratios (ORs) with 95 % confidence intervals (CIs). The hypothesized contextual phenomenon (*Random effects - measures of variation*) was measured by the ICC, VPC, PCV and MOR.(67) The formula for calculating PCV and MOR for a two-level multilevel modelling are as for a three-level multilevel modelling described below in study V. For ICC estimation of two-level multilevel modelling, the formula below was used;

$$\text{ICC} = \frac{V_n}{V_n + \left(\frac{\pi^2}{3}\right)}$$

V_n depicts neighbourhood level variance.

Results: The overall childhood stunting prevalence in this study was approximately 26% i.e. 7322 out of the 28, 647 under-fives studied had stunted growth.

Fixed effects

After adjusting for all variables in the final model 4, the following individual level factors (level 1) independently reduced the odds of childhood stunting: being an older child, female sex, single birth product, birth weight ≥ 2.5 kilograms, adequate child spacing interval, maternal age between 35 to 49 years (OR 0.91; 95% CI 0.82 – 0.99), mother attained secondary (OR 0.84; 95% CI 0.64 – 0.97) or higher education (OR 0.75; 95% CI 0.35 – 0.86), highest level of maternal health seeking behaviour index, normal and high maternal BMI, not too prolonged breastfeeding and household belongs to richest wealth index quintile. On the contrary, after controlling for all other variables in model 4, the neighbourhood-level factors (level 2) of being a resident of north west (OR 1.26; 95% CI 1.14 – 1.29) and north east (OR 1.35; 95% CI 1.27 – 1.43) compared to North central and living in neighbourhood with high illiteracy rate (OR 1.49; 95% CI 1.19 – 1.88) compared to low illiteracy rate increased the odds of childhood stunting in our study population.

Random effects

There were statistically significant neighbourhood variations in the log odds of childhood stunting in Nigeria. The neighbourhood-level factors in our study explained approximately about 8% of the total individual variance with respect to childhood stunting. The result of MOR for the neighbourhood-level contextual effects was moderate with MOR of 1.5 in the final model.

STUDY III:

Title: The logistic regression and receiver operating characteristic (ROC) analyses of individual, household, and area-level factors for predicting childhood mortality in Nigeria

Objective: To identify and determine the predictors of childhood mortality in Nigeria

Method: Multivariable logistic regression analysis to identify factors that would be useful in predicting childhood mortality in Nigeria was conducted. Individual, household and area-level factors with various independent variables were explored. The dependent variable was under-five mortality (childhood mortality). Utilizing the function of logistic regression, probability plot (PP) value was sought for at estimating the occurrence of childhood mortality. ROC curve for checking the predictive power of the final model was constructed as well as PP- value calculated. The area under the curve (AUC) of the final model with the 95% confidence intervals (CIs) was also calculated. The fitness of the final model was done through regression diagnostics including Likelihood Ratio (LHR) and Hosmer-Lemeshow model fit tests. Variance Inflation Factors (VIF), reciprocal of VIF and estimates of adjusted R square were used to rule out the presence of multicollinearity. (68;69)

Results: The prevalence of under-five mortality was 142 deaths per 1000 live births in the study sample. In study III, the final model showed that the probability of childhood mortality is reduced by 20% (OR 0.80; 95% CI 0.70 – 0.90) if the mother had first marriage between the age of 20 to 24 years and by 30% (OR 0.70; 95% CI 0.57 – 0.85) if the mother had first marriage by age 25 years or more when compared to a mother who married at her teen age.

After controlling for other factors; the following maternal level factors such as usage of contraception and average level of maternal health seeking behaviour reduced the odds of childhood mortality by 31% and 94% respectively. Other maternal factors like short preceding birth interval and breastfeeding child for less than 18 months increased the odds of childhood mortality. The child factors of high birth order and birth weight of < 2.5kilograms also increased the odds of childhood mortality. The following household level factors; large household size (OR 3.54; 95% CI 3.07 – 4.08), polygamous family settings, urban residency and unhygienic neighbourhood environment all increased the likelihood of childhood mortality. The AUC of the final model was about 95% which implies that the predictive power of the model was excellent. The negative predictive value of the final model was about 96% and the positive predictive value of about 67%.

STUDY IV:

Title: Factors that predict differences in childhood mortality in Nigerian communities: a prognostic model

Objective: To identify predictors of childhood mortality differences between Nigerian communities and to identify outlier communities where childhood mortality was worse than expected.

Method: Prognostic multivariable mixed model was constructed to explain the observed differences between communities regarding childhood mortality. We adopted this method which has been used and proved to be scientifically sound by Harrell(70) and Freemantle(71) and their colleagues in a couple of studies in the developed countries. Precisely, Poisson mixed model was constructed where the response variable was the observed number of deaths of under-five children per 1000 live births.

The associations of childhood mortality rates with each characteristic of individuals in the community were first examined at the univariable level. Characteristics statistically associated with childhood mortality in the univariable Poisson models subsequently were fitted in multivariable Poisson regression model. The final model was used to predict the death rates for each community and compared the predicted and observed death rates. The observed and predicted rates were described and plotted. High risk communities were defined as those communities for which the observed death rates differed from the expected rates of more than three studentized residual deviances.(71) We computed the degree to which variation (extra-Poisson variability) between the communities was attributed to the included parameter terms. P value of < 0.05 was used to define statistical significance. Regression diagnostics were used to judge the goodness-of-fit of the model. They included Likelihood Ratio (LHR) and Hosmer-Lemeshow model fit

tests. Variance Inflation Factors (VIF), reciprocal of VIF and estimates of adjusted R square were used to rule out the presence of multicollinearity.

Results: Rates of childhood mortality varied across the communities with mean of about 79.3 per 1000 live births and standard deviation (SD) of 63.7 for the 5 years of this study. After adjusting for all other variables in the final model, the risks of childhood mortality was significantly increased by 14% for every SD increase in communities' multiple childhood deprivation score (RR =1.14, 95% (CI) 1.09 - 1.19) and by 22% with every SD increase in communities' maternal socioeconomic deprivation score (RR= 1.22, 95% CI 1.14 - 1.29). Conversely, the risks of childhood mortality was significantly reduced by 15% for every SD increase in communities' maternal health seeking behaviour index (RR = 0.85, 95% CI 0.80 - 0.91) and by 16% for every SD increase in communities' environmental factor index score (RR = 0.84, 95% CI 0.78 - 0.90). In the same vein, the risks of childhood mortality is reduced by 4% for every SD increase in communities' ethnicity diversity index score (RR = 0.96, 95% CI 0.94 - 0.97). The final model accounts for approximately 64% of the variations observed in the likelihood of childhood mortality across the communities studied. Our study also showed that 11 of the 896 communities studied had significantly higher than expected childhood mortality rates as evidenced by the observed rates been differed from the predicted rates by more than three studentised residual errors.

STUDY V:

Title: Contextual socioeconomic factors associated with childhood mortality in Nigeria: a multilevel analysis

Objective: To examine whether neighbourhood socioeconomic disadvantage predicts childhood mortality beyond individual-level measures of socioeconomic status

Method: Multilevel logistic regression was used to study the association between individual-, neighbourhood-, and state-level socioeconomic factors and childhood mortality. A multi-level modelling technique was used (65-67) to identify clustering of childhood mortality within neighbourhoods and the states in Nigeria. A three-level multilevel model for binary response for childhood mortality *y* (with y = 1, if the child died) was specified for individuals i residing in neighbourhood j from state k of the form:

$$\pi_{ijk} : y_{ijk} \sim Bernoulli\,(1, \pi_{ijk})$$

Probability was related to a set of categorical predictor *X* and a random effect for each level by a logit-link function as

$$logit(\pi_{ijk}) = \log[{\pi_{ijk}}/{(1-\pi_{ijk})}] = \beta_0 + \beta_1 X_{ijk} + \beta_2 X_{jk} + \beta_3 X_k + u_{0jk} + v_{0k}$$

The linear predictor on the right side of the equation comprised of a fixed part ($\beta_0 + \beta_1 X_{ijk} + \beta_2 X_{jk} + \beta_3 X_k$) estimating the conditional coefficients for the determinant variables and two random intercepts linked to neighbourhoods (u_{0jk}) and state(v_{0k}), with each assumed to have an independent and similar distribution and variance calculated at each level.

Modelling:

We constructed four models. The first model, a null model without any determinant variables, was specified to decompose the amount of variance that existed between the neighbourhood and state levels. The second model comprised of individual-level socioeconomic variables while the third and fourth models were extended to include neighbourhood-level and state-level measures of socioeconomic status variables respectively.

Fixed effects (measures of association)

The association between childhood mortality and socioeconomic status was shown as odds ratios (ORs) with 95 % credible intervals (CrIs).

Random effects (measures of variation)

The hypothesized contextual phenomenon was measured by the intraclass correlation (ICC), (72) variance partition coefficient (VPC), percentage change in variance (PCV) and median odds ratio (MOR).(67)

Proportion of variance as a result of differences between states

= semblance of study participants in the same state

= intra-state correlation (ICC_s)

$$= \frac{V_c}{V_n + V_c + \left(\frac{\pi^2}{3}\right)}$$

Proportion of variance as a result of differences between neighbourhoods

= semblance of study participants in the same neighbourhood

= intra-neighbourhood correlation (ICC_n)

$$= \frac{V_n + V_c}{V_n + V_c + \left(\frac{\pi^2}{3}\right)}$$

V_n is the neighbourhood variance and V_c, the state variance. A high ICC in the null model implies high clustering of childhood mortality in the neighbourhood or state which means a strong neighbourhood and state contextual effect on childhood survival. Low ICC on the other hand, implies the existence of a weak neighbourhood and state effects on childhood survival.

The percentage change in variance implies variance attributed to different variables estimated from the formula below;

$$PCV = \left\{\frac{V_{initial} - V_{after}}{V_{initial}}\right\} X\ 100$$

$V_{initial}$ depicts the variance in the null or empty model and V_{after}, implies the variance in the different models as the case may be.

Median odds ratio (MOR)

The MOR estimates the second or third level (neighbourhood or state) variance as an odds ratio and calculates the probability of childhood survival that can be linked to neighbourhood and state influences. MOR of 1 implies absence of neighbourhood or state variance as the case may be. On the contrary, the higher the MOR, the more significant are the contextual influences for understanding the likelihood of childhood mortality. MOR can be calculated by using the formula below

$$MOR = e^{\left(\sqrt{2V_n} \times 0.675\right)} \approx e^{0.95\sqrt{V_n}}$$

V_n is the second or third level variance i.e. neighbourhood or state variance while 0.675 is the 75th percentile of the standard normal distribution with mean of 0 and variance of 1.

Results: Prevalence of childhood mortality was about 130 per 1000 live births as estimated from the dataset across the 37 states.

Fixed effects

After adjusting for all other variables in model 4[d], the following individual level factors (level 1) independently reduced the odds of childhood mortality: female sex, maternal age between 25 to 34 years (OR 0.90; 95% CrI 0.81 – 0.98), mother attained secondary (OR 0.79; 95% CrI 0.67 – 0.91) or higher education (OR 0.68; 95% CrI 0.50 – 0.88). However, being a member of poorer (OR 1.55; 95% CrI 1.25 – 1.93) and poorest households (OR 1.41; 95% CrI 1.12 – 1.79) regarding wealth index quintiles respectively increased the odds of childhood mortality. Likewise after controlling for all other variables in model 4[d], the neighbourhood-level factors (level 2) of being a resident of rural area (OR 1.25; 95% CrI 1.08 – 1.43) and living in neighbourhood with high poverty rate (OR 1.22; 95% CrI 1.05 – 1.43) increased the odds of childhood mortality in our study population.

Random effects

There were statistically significant neighbourhood and states variations in the log odds of childhood mortality in Nigeria. The neighbourhood and state level socioeconomic factors explained approximately about 8% and 3% of the total individual variance with respect to childhood mortality in this study. The result of MOR for the neighbourhood-level contextual effects was moderate with MOR of 1.4 while it was very little with MOR of 1.1 for state-level contextual effects in the final model.

DISCUSSION

Main findings

Study I reveals the wide variations that exist between the 37 states in Nigeria regarding childhood stunting using within-data analysis triangulation procedure. Three different analytical procedures of spatial cluster analysis, league table and control charts were used to ensure cross-verifications of the procedures which ultimately removes concerns about the reliability of our analysis. To the best of our knowledge, this is the first study that incorporated control charts in evaluating childhood stunting in sub-Saharan Africa. The three analytical procedures used in study I recognized eleven states of Kano, Niger, Kebbi, Katsina, Yobe, Zamfara, Sokoto, Gombe, Jigawa, Borno and Bauchi all from northern part of the country as having highest percentage of childhood stunting. Similar findings have been documented in previous studies which showed that residing in certain geopolitical zones may have untoward effect on health outcomes. (73-76) On the other hand, eight states of Lagos, Rivers, Anambra, Enugu, Akwa Ibom, Bayelsa, Imo and Abia all from Southern part of Nigeria were recognized by all the three analytic procedures as having lowest percentage of childhood stunting. From the result of study I, we can conclude that there are 'special practices' from the northern states that could be considered bad practices and from southern states that could be identified as good practices. These practices from the two regions deserve further investigations particularly when considering interventions to adopt at reducing the high prevalence of childhood stunting in the country. One very good practice that may likely be responsible for low prevalence of childhood stunting in the southern states could be the preschool and elementary school feeding programmes of some state governments which ensures that protein-rich foods are freely given to the pupils.

Study II highlights the significance of neighbourhood differences regarding stunting in under-five children. The study revealed that approximately 50% of variance in childhood stunting in our final model was linked to neighbourhood-level factors. The findings of reduced odds of stunting in children aged 48 – 59 months when compared to children aged 12 – 23 months in this study is consistent with findings of prior studies from the developing countries.(77;78) A reasonable explanation for this association could be that most women carry out full weaning on their children during the period when they are about 12 – 24 months old which make the children to be more prone to having stunted growth. Consistent with prior studies that investigated the association between childhood mortality and stunting with gender of a child, (79-82) results from study II showed that female children had reduced odds of childhood stunting compared to their male counterparts. A plausible explanation could be because female children often times are given special attention by their parents in some cultures due to the high value placed on women for agricultural labour.(83;84) Children of multiple births from this study were found to have higher odds of childhood stunting compared to their counterparts from single birth which is in agreement with outcomes of previous studies.(41;42;77;85) Insufficient nutritional intake and breastfeeding coupled with low birth-weight that is more common in multiple births children could be linked to this finding.

Children of mothers with no formal education in this study had increased odds of stunting compared to the children of the educated mothers which support findings of other similar studies.(86-89) This finding could be attributed to the fact that educated mothers most times have average to high MHSBI and are better at accessing information vital for preventing childhood stunting from occurring or lessen the degree if it occurs.

The results of this study also corroborate the findings of other similar studies that low maternal BMI increased the odds of childhood stunting. (90;91) One may however disagree with this finding and say maternal height should be a better yardstick or indicator for evaluating this relationship; to the best of our knowledge, no study has been able to support this notion. Breastfeeding beyond 12 months was found to be associated with stunted growth in this study and this could be linked to poverty that is very common in the developing world where parents are unable to feed their children with sufficient and quality complementary foods. They therefore do not supplement breastfeeding with any complementary food and continue with exclusive breastfeeding beyond 12 months.(92-94) In addition, a study conducted by Brakohiapa and colleagues have attributed this relationship to situations where some children refused other foods except breast milk.(95)

We found reduced odds of stunting in children from wealthy households compared to the ones from poor households, finding which is consistent with what has been previously reported in literature.(86;96-99) Being wealthy most times translates to having access to good and basic health care services when sick in the developing world where hardly do they practice publicly funded health care system as is being done in most developed countries. In addition, good and nutritious foods needed for proper growth and development of children are likely to be found in such households. Neighbourhoods with high illiteracy rates in this study were found to have increased odds of childhood stunting when compared with neighbourhoods with low illiteracy rates which is in agreement with findings of prior studies.(100-102)

Result of study II supports the findings of a growing body of literature advocating for the use of multilevel modelling to unravel the effects of neighbourhood level contextual influences predisposing people to health outcomes such as morbidity and mortality.

The findings from study III revealed the risk factors associated with childhood mortality in Nigeria. We adjusted for the effects of potential confounders by inclusion of several individual, household and community-level parameters in our analyses without over-fitting of the final model. Consistent with findings of previous studies, (103;104) children of mothers who had their first marriage at teen ages had higher odds of dying compared to those who married after teen ages. The plausible explanation for this may be that teen mothers are inexperienced in caring for the under-fives and often times have financial difficulties to access health care services that are important for child survival. Children of mothers who used contraception in our study were less likely to die compared to those of mothers who do not. This finding was in agreement with result of previous studies (105;106) and a possible explanation is the fact that with contraception, children that were planned for will come to life which would increase their probability of surviving. Birth interval of ≥ 18 months in this study reduced the odds of childhood mortality which did not contradict the findings of previous studies.(107;108) Risk of obstetrics complication is known in medical field to be lowered if a mother had enough/adequate birth interval before having another child and that such a mother would have regained most of body nutrients lost during the preceding pregnancy, child birth and breastfeeding. A child with high birth order number from this study had increased odds of dying which is consistent with findings of previous studies from developing countries.(109;110)

There is bound to be increased competition for food and other scarce household resources essential for proper growth and survival as the birth order of a child increases which ultimately increases the likelihood of the child not surviving beyond fifth birthday. This study also showed that children with low birth weight were more likely to die compared to those with normal birth weight which is in agreement with what has been reported previously.(106;108;111) Children with birth weight < 2.5 kg most times were given birth to prematurely with under-developed organs and are more susceptible to having sepsis which is a number one cause of neonatal mortality in developing world. Consistent with findings of other studies,(112-114) we found that children from the rural areas had higher odds of dying compared to the ones from urban areas. Plausible explanation may be that children from the rural areas are unlikely to have access to essential health care services that are vital for survival. Maternal health seeking behaviour in our study had protective association with childhood survival and this finding supports those of other similar studies.(113;115) Such mothers would imbibe the habit of having their children receive immunization against preventable childhood killer diseases. In addition, they have the knowledge of how to prepare and administer Oral Rehydration Therapy (ORT) as well as having hospital based child birth. This study also revealed that proper disposal of wastes at home through good toilet facilities increases the likelihood of a child surviving beyond age 5 years. Similar findings have been reported in prior studies.(116-118) Polygamous family setting which invariably leads to large family size was also found to increase the odds of childhood mortality in our study and a good explanation for this outcome could be that availability of food and other household resources essential for childhood survival would reduce. This result is in agreement with those of other similar studies.(119;120)

Furthermore, this study showed that children residing in the North central region of Nigeria had higher odds of childhood mortality compared to their counterparts from the South east region of the country. Prior studies (121;122) carried out in the developing world have reported regional variations in childhood mortality and this could be as a result of differences in climatic conditions across various regions. Regions rich in mineral resources as well as agricultural resources tend to be the best regions for optimal survival.

We developed a prognostic model in study IV to predict differences in UFMR at the level of neighbourhoods in Nigeria using available national representative dataset. The final model accounts for about 64% of the variations in UFMR between the neighbourhoods. The model fit tests conducted confirmed that the final model was well fitted indicating that the results of our study is generalizable, although with caution, given similarities in socioeconomic and demographic profiles of countries in sub-Saharan African. Children with higher indices of multiple childhood deprivation have higher risk of UFM compared with those with lower indices of multiple childhood deprivation which is in agreement with finding of similar studies.(123-125) A plausible explanation for this association could be that the amount of time for care that a mother has for a child is reduced if the birth interval is short. (126-129) Similarly, higher indices of maternal socioeconomic disadvantage increased the risk of UFM in this study which is also consistent with findings of previous studies.(130-133) A community that is socieconomically disadvantaged is a community in which individuals residing in it would not be able to afford essential goods and services such as health care services, transportation and medications because health care delivery system is not publicly funded in most developing countries. This study further revealed that an hygienic community environment has positive effect on childhood survival which is consistent with finding of

previous studies. (134;135) This relationship could be linked to the fact that a clean environment with safewater and good waste disposal system will not be conducive for disease causing microorganisms and other contagions to thrive in.

The results of this study also corroborate the findings of other similar studies(113;115) that high MHSBI confers protection against UFM and other health outcomes. Mothers with high health seeking behaviour will have good habit of seeking medical attention such as attending antenatal clinic while pregnant. Moreover, such mothers will make sure their children receive immunization against preventable childhood killer diseases.

Study IV further showed that high ethnicity diversity index has protective effect on childhood survival with similar findings reported in prior studies. (136;137) This relationship could be linked to cultural, educational, and socioeconomic differences of various ethnic groups constituting a given population. For example, polio is still endemic in the northern part of Nigeria which is predominantly dominated by the Hausa/Fulani ethnic groups who do not want their children get vaccinated against polio virus because they believe that polio vaccine for prevention of polio disease contains anti-fertility agent and HIV virus.(138;139) Therefore, polio immunization acceptance in these ethnic groups is seen as an indirect method of controlling their population growth by the western countries. Consistent with findings of other studies investigating differences in UFMR at regional health services and geopolitical zones context, (140-142) we found that a number of communities had considerably higher than predicted UFMR.

Study V highlights the significant roles that individual and neighbourhood socioeconomic disadvantage play at explaining heterogeneity regarding under-five mortality in Nigeria. This study revealed that socioeconomic status of the neighbourhood

where an individual lives is associated with childhood survival after adjusting for both individual and state level socioeconomic status.

Consistent with prior studies (25;143;144) that investigated the association between childhood mortality and gender of a child, our study showed that female children had higher odds of survival compared to their male counterparts. A plausible explanation could be because female children often times have smaller body size during pregnancy and child birth that enhances easy passage through the birth canal and prevents birth trauma and asphyxia, thereby lowering the number of deaths recorded during neonatal period.(145) In agreement with findings of previous studies, (146-148) children of mothers who are aged 15 – 24 years had higher odds of dying compared to those from mothers who are aged 25 – 34 years and a possible reason for this finding may be that teen mothers are inexperienced in caring for the under-fives and often times have financial difficulties to access health care services that are vital for child survival. In addition, teenage mothers have been described in a study as having less matured body organs such as narrow pelvic bone leading to obstructed labour and increased risk of neonatal mortality. (148)

Children of mothers with no formal education in this study had increased likelihood of dying compared to the children of educated mothers which supports findings of other similar studies.(132;149-151) This finding could be attributed to the fact that educated mothers most times have average to high MHSBI and are better at accessing information vital for preventing childhood mortality from occurring. We found reduced odds of dying in children from wealthy households compared to the ones from poor households, finding which is consistent with what has been previously reported in literature.(131;152;153) Being wealthy often times translates to having access to good and

basic health care services when sick in the developing world where hardly do they practice publicly funded health care system as is being done in most developed countries. In addition, good and nutritious foods needed for proper growth and development of children are not likely to be found in such poor households. The observed association between residing in rural settings and increased odds of childhood mortality could be explained by the fact that good and basic health care facilities to take care of sick children are often not found in rural areas of the developing countries. Neighbourhoods with high poverty rates in this study were found to have increased odds of childhood mortality when compared with neighbourhoods with low poverty rates which is in agreement with findings of prior studies which were however not limited to children aged 0 to 5 years but 0 to 14 years.(130;154;155) About 8% and 3% of the total individual variance in the odds of under-five mortality in this study occurred at the neighbourhood and state level respectively. Theoretical assumption in the field of social epidemiology postulates that people residing in the same neighbourhood would resemble one another regarding health outcomes compared to those from different neighbourhood.(156) As a result of differences in sociocultural, economic and geographical contexts where people found themselves in different parts of the world, people with different characteristics may have the same health outcomes depending on whether they reside in one neighbourhood or another.(156) Thus, people living in the same area tend to have similar health outcomes i.e. clustering, which may likely be as a result of being prone to the same circumstantial or area influences.(156) In light of this, we might conclude in our study that there are neighbourhoods and states-level circumstantial factors influencing childhood survival in Nigeria; and more importantly neighbourhoods are very vital when trying to comprehend why there are variations in childhood mortality in Nigeria.

Study limitations

There are a number of precautionary measures to take when interpreting the results of this body of research work. First and foremost, the cross-sectional nature of the design of all the studies in this thesis limits our ability to draw causal conclusions. In other words, the relationships observed in all the studies should be construed as associations only. Another important limitation to consider is the term "neighbourhood or community" used to depict area of residence may not adequately capture the socioecological context for determination of human's health(157) because they are only administrative divisions designed for survey purposes. Moreover, the extent of exposure of the participants to neighbourhood socioecological risk markers could not be ascertained as information regarding the length of time they have been residing in the neighbourhoods was not collected in the survey. Therefore, we were not able to completely ascertain whether the correlations of the included neighbourhood risk markers with childhood mortality and stunting were due to cumulative effects of being exposed to these attributes. Furthermore, we used indirect measure of household wealth status which we could be criticized for, however, asset based composite index used in DHS has been considered to be a good alternative for measuring household wealth status in lieu of income and expenditure data that would have been the ideal. Lastly, recall bias is a common problem with this type of study as there might have been under-reporting of births and deaths of children that died in the more distant past before the survey particularly by the illiterate women which may have altered the mortality estimates.

Study strengths

It is important to mention some of the strengths of this study. An important strength of this study is the representativeness of data used. Thus, the findings of this body of work are generalizable to the studied population and other countries with similar population. The adoption of multistage sampling technique for the survey which ultimately eliminated the possibility of selection and sampling bias gives reliability to the dataset used. It is also vital to point out that the data of DHS have been internationally acknowledged to be of high quality as the surveys that generated them are based on sound sampling techniques and participants' response rate of over 90%. In addition, DHS data is the best data available in developing countries and is widely used by both national and international health organizations; therefore its usage for this thesis gives credibility to the worthiness of this study.

There are merits to studying risk markers (factors) associated with childhood mortality and morbidity using multilevel analytical approach; the state and neighbourhood level analyses would help determine the socioecological, economic as well as cultural contexts where people reside and experience health outcomes. Aside the neighbourhoods, individuals will be affected by state, regional and national governmental programmes and policies which in turn will influence the proximate determinants of health outcomes. In light of this, we were able to examine the influence that various levels of societal hierarchy exerts on our lives, which gives strong evidence about individual, neighbourhood and state-level socioeconomic factors' association with childhood survival and morbidity. Our study also reveals that it is possible to examine neighbourhood contextual factors through creation of composite indices to largely predict and explain differences in childhood mortality rates between communities in Nigeria, which has potential to increase the statistical power for testing the associations.

Study implications and recommendations

The findings of this thesis revealed that childhood mortality and stunting in Nigeria are major public health problems needing interventions. The study provided proof that, contextual effects, related to individual's area/neighbourhood of residence seem to have some influence on health outcomes (childhood mortality and morbidity).

Thus, public health programmes and policies should therefore target both areas/neighbourhoods and individuals which make health issues not to be solely an individual's responsibility but also public responsibility. The government need to be aware that the health of the citizens may depend on the contextual effects of their neighbourhoods. Areas characterized by inadequate social amenities, high poverty rate, high illiteracy rate, poor environmental and sanitary conditions, overcrowded or deteriorating houses have collective properties of exerting negative influence on the individual resident's health independent of individual-level risk factors. Any intervention by governmental and non-governmental organizations aimed at reducing childhood mortality and stunting should consider neighbourhoods/areas with all the aforementioned characteristics so as to avert under-coverage of neighbourhoods/areas that deserve it.

Furthermore, a universal approach linking FMOH with health related ministries like Federal Ministry of Education, Women Affairs, Agriculture and Labour should be adopted because provision of jobs and women empowerment would ultimately have impacts on childhood mortality and morbidity. Lastly, public health prevention strategies such as establishment of publicly funded health care services, poverty alleviation programmes and health education should be implemented at both individual level and contextual level.

Future studies

Future studies such as interventional, case control and cohort studies should examine other factors that may be responsible for the unexplained community and states heterogeneity in childhood mortality and stunting in Nigeria. Further research should also scrutinize the mechanisms that link individuals and neighbourhoods together, in other words, the process through which detrimental neighbourhood influences and effects are transferred to the individual residents of the neighbourhood. Demystifying these mechanisms is vital to the design of effective contextual level interventions due to the fact that these mechanisms or processes may be more responsive to modifications than the firmly established intrinsic properties of the neighbourhoods such as high poverty and illiteracy rates. Well designed and properly implemented prevention strategies are needed to reduce the burden of childhood mortality and morbidity in Nigeria. These interventions should be aimed at the determinants of poor environmental conditions and arrays of factors that can be broadly classified as behavioural such as shared preferences, values, cultural and political influences. Modifications of these factors for better may help significantly at reducing the high and unacceptable childhood mortality and morbidity in Nigeria and other countries with similar settings.

CONCLUSIONS

By adopting multilevel modelling approach, we added to the growing body of evidence; the effects of the neighbourhood contextual influences on childhood survival and stunting in Nigeria. Our study revealed that individual, neighbourhood and socioecological contexts where a child lives were associated with childhood mortality and stunting. Efforts at reducing the burden of childhood mortality and stunting should be directed at establishment of poverty alleviation programmes, effective publicly funded health care delivery, promotion of hygienic environmental practices and health education more importantly at the neighbourhood level. Furthermore, governmental and non-governmental organizations should direct their efforts regarding interventions that also include enlightenment campaigns on the contextual level factors at the neighbourhood level rather than singly on individual level factors for meaningful impacts to be made. Given the importance of socioecological factors at influencing the lifestyles of neighbourhoods and individuals, interventions targeting structural make up of these two parameters is vital towards achieving MDGs 4 and 1 regarding childhood mortality and stunting in developing countries.

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APPENDIX I: CO-AUTHORS' STATEMENTS OF CANDIDATE'S CONTRIBUTION

PhD by published work, Warwick Medical School, University of Warwick

Statement of contribution by Victor Tunde Adekanmbi

Paper to be considered as part of the PhD by published work

Adekanmbi V T, Uthman O A, Mudasiru O M. Exploring variations in childhood stunting in Nigeria using league table, control chart and spatial analysis. *BMC public health* 2013; 13:361

Contribution of candidate: Victor Adekanmbi took a lead role in the study design, coding scheme and statistical method. He managed and coded the study data, performed the statistical analysis, took lead in writing the manuscript in liaison with co-authors and responded to reviewers as corresponding author.

I agree that Victor Adekanmbi made the aforementioned contribution to the paper.

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Paper to be considered as part of the PhD by published work

Adekanmbi V T, Kayode G A, Uthman O A. Individual and contextual factors associated with childhood stunting in Nigeria: a multilevel analysis. *Maternal & child nutrition* 2013; 9:244 - 59

Contribution of candidate: Victor Adekanmbi took a lead role in the study design, coding scheme and statistical method. He managed and coded the study data, performed the statistical analysis, took lead in writing the manuscript in liaison with co-authors and responded to reviewers as corresponding author.

I agree that Victor Adekanmbi made the aforementioned contribution to the paper.

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Statement of contribution by Victor Tunde Adekanmbi

Paper to be considered as part of the PhD by published work

Kayode G A, **Adekanmbi V T,** Uthman O A. Risk factors and a predictive model for under-five mortality in Nigeria: evidence from Nigeria demographic and health survey. *BMC pregnancy and childbirth* 2012; 12:10

Contribution of candidate: Victor Adekanmbi was actively involved in the drafting of the manuscript and statistical analysis, responding to reviewers comments and revising the manuscript critically for important intellectual content. In addition, he gave final approval for the version to be published.

I agree that Victor Adekanmbi made the aforementioned contribution to the paper.

Name	Signature	Date
Gbenga Kayode		09/07/2015
Olalekan Uthman		08/07/2015

PhD by published work, Warwick Medical School, University of Warwick

Statement of contribution by Victor Tunde Adekanmbi

Paper to be considered as part of the PhD by published work

Adekanmbi V T, Kandala N B, Stranges S, Uthman O A. Factors that predict differences in childhood mortality in Nigerian communities: a prognostic model.

Journal of Paediatrics 2015; DOI:10.1016/j.jpeds.2015.09.057

Contribution of candidate: Victor Adekanmbi took a lead role in the study design, coding scheme and statistical method. He managed and coded the study data, performed the statistical analysis, took lead in writing the manuscript in liaison with co-authors and responded to reviewers as corresponding author.

I agree that Victor Adekanmbi made the aforementioned contribution to the paper.

Name	Signature	Date
Ngianga-Bakwin Kandala	[redacted]	09/07/2015
Saverio Stranges		08/07/2015
Olalekan Uthman		08/07/2015

PhD by published work, Warwick Medical School, University of Warwick

Statement of contribution by Victor Tunde Adekanmbi

Paper to be considered as part of the PhD by published work

Adekanmbi V T, Kandala N B, Stranges S, Uthman O A. Contextual socioeconomic factors associated with childhood mortality in Nigeria: a multilevel analysis. *Journal of Epidemiology & Community Health* 2015; *69:1102-1108. DOI: 10.1136/jech-2015-205457*

Contribution of candidate: Victor Adekanmbi took a lead role in the study design, coding scheme and statistical method. He managed and coded the study data, performed the statistical analysis, took lead in writing the manuscript in liaison with co-authors and responded to reviewers as corresponding author.

I agree that Victor Adekanmbi made the aforementioned contribution to the paper.

Name	Signature	Date
Ngianga-Bakwin Kandala	[redacted]	09/07/2015
Saverio Stranges		08/07/2015
Olalekan Uthman		08/07/2015

APPENDIX II: ALL PUBLICATIONS BY CANDIDATE

- **Adekanmbi, V.T.,** Kandala, N.B., Stranges, S., Uthman, O.A. (2015). Factors that predict differences in childhood mortality in Nigerian communities: a prognostic model. *Journal of Paediatrics 2015; DOI:10.1016/j.jpeds.2015.09.057*

- Adedigba, M.A., **Adekanmbi, V.T**., Asa, S.S., Ibiyemi, F. (2015). Pattern of Utilization of Dental Health Care among HIV-positive Adult Nigerians. *Oral Health & Preventive Dentistry – In press*

- **Adekanmbi, V.T.,** Kandala, N.B., Stranges, S., Uthman, O.A. (2015). Contextual socioeconomic factors associated with childhood mortality in Nigeria: a multilevel analysis. *Journal of Epidemiology & Community Health* 2015; *69:1102- 08. DOI:10.1136/jech-2015-205457*

- Oga, E., Brown, J., Brown, C., Dareng, E., **Adekanmbi, V.,** Odutola, M., Olaniyan, O., Offiong, R.A., Obende, K., Adewole, S., Achara, P., Dakum, P., & Adebamowo, C. (2015). Recurrence of cervical intra-epithelial lesions after thermo coagulation in HIV+ and HIV- Nigerian women. *Annals of Global Health, 81, (1) 99. DOI:10.1016/j.aogh.2015.02.729*

- Afolabi, A.O., Adedigba, M.A., **Adekanmbi, V.T**., (2014) Evaluation of oral health among pregnant women in a Nigerian population. *East African Journal of Public Health Vol 11, No 1 (2014)*

- **Adekanmbi, V.T**., Kayode, G.A., Uthman, O.A. (2013). Individual and contextual factors associated with childhood stunting in Nigeria: A multilevel analysis. *Maternal & Child Nutrition 2013; 9:244 – 59. DOI: 10.1111/j.1740-8709.2011.00361.x*

- **Adekanmbi, V.T**., Uthman, O.A., Mudasiru, O.M. (2013). Exploring variations in childhood stunting in Nigeria using league table, control chart and spatial analysis. *BMC Public Health 2013, 13:361. DOI: 10.1186/1471-2458-13-361*

- Uthman, O.A., Kayode, G.A., **Adekanmbi, V.T**. (2013). Individual and contextual socioeconomic determinants of knowledge of the ABC approach of preventing sexual transmission of HIV in Nigeria: a multilevel analysis. *Sexual Health Journal 2013 Nov; 10(6):522-9. DOI: 10.1071/SH13065*

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- Egbewale, B.E., Uthman, O.A., Odu, O.O., **Adekanmbi, V.T**. (2012). Behavioural interventions for preventing HIV infection in homeless or unstably-housed adults. (Protocol). *Cochrane database of systematic review 2012, Issue 1. DOI:10.1002/14651858.CD009575*

- Kayode, G.A., **Adekanmbi, V.T**., Uthman, O.A. (2012). Risk factors and a predictive model for under-five mortality: Evidence from 2008 Nigeria Demography and Health Survey. *BMC Pregnancy and Childbirth 12, (1):10. DOI:10.1186/1471-2393-12-10*

APPENDIX III: THE PUBLISHED WORK