Where do they live and what are the individual and contextual factors predisposing children to severe acute malnutrition in sub-Saharan Africa

Abstract

Introduction: Reduction of malnutrition, especially severe acute malnutrition (SAM) is very crucial, directly or indirectly, to a targeted decrease in child mortality and improvement in maternal health. We aim to develop and test a model of risk factors associated with SAM among under-five children in SSA countries.

Methods: We used 33 recent Demographic and Health Survey (DHS) data collected between 2010 and 2018 in SSA countries. We used multivariable Bayesian logistic multilevel regression models to analyse the association between individual compositional and contextual factors associated with SAM.

Results: We analysed information on 210,289 under-five children (Level 1) nested within 17,529 neighbourhoods (Level 2) from 33 SSA countries (Level 3). The prevalence SAM ranged from 0.5% in South Africa to 8.8% in Nigeria. Male children, infants, and children from rural areas, neighbourhoods with high illiteracy and high unemployment rates and those from coutries with high intensity of deprivation and high rural population percentage were more likely to have SAM.

Conclusion: Individual compositional and contextual factors were significantly associated with SAM.

Keywords: severe acute malnutrition, low and middle-income countries, Bayesian, Under five children

Introduction

Malnutrition is one of the top killer diseases among under-five children in sub-Saharan Africa (SSA) countries and accounts for about a third of preventable deaths among children (R. Black et al., 2008; WHO, 2009a, 2019). Reduction of malnutrition, especially SAM is very crucial, directly or indirectly, to a targeted decrease in child mortality and improvement in maternal health (United Nations, 2015; WHO, 2019).

While the burden of SAM is higher among the SSA countries than in other countries, inequalities exist in its distribution within these countries. The particular people affected by SAM within the SSA countries and where they live in the SSA countries have not been exploited. Rather than using “one cap fits all approach” in the implementation of an intervention aimed at reducing the burden of SAM in these countries, the identification of the most affected sub-population group and where they live will enable the adoption of appropriate approaches that can substantially reduce the burden. The knowledge of this information and its adoption could further reduce the case-fatality rate of SAM beyond the current 55% in hospital settings as stipulated by WHO (WHO, 2019). The WHO had reported that the management of severe acute malnutrition according to WHO guidelines in hospital settings use of ready-to-use therapeutic foods reduce the fatality of SAM.

The UNICEF framework also identified the short-term consequences of malnutrition to include mortality, morbidity and disability. The identified long term and intergenerational consequences include adult height, cognitive ability, economic productivity, reproductive performance, metabolic as well as cardiovascular diseases (UNICEF, 2013). A child with SAM and other medical issues are more difficult to manage. The medical complications with SAMare enormous. They include severe pneumonia, shock, dehydration, convulsions, blinding eye signs, congestive heart failures, severe anaemia, hypoglycaemia, hypothermia, anorexia, poor appetite, intractable vomiting. Hypothermia, high fever etc(R. E. Black, Laxminarayan, Temmerman, Walker, & World Bank., 2016; Lenters, Wazny, & Bhutta, 2016).

While a number of studies(Abdulahi, Shab-Bidar, Rezaei, & Djafarian, 2017; Akombi et al., 2017; Fantay, Mekonnen, Haftom, Oumer, & Afework, 2019; Khan, Zaheer, & Safdar, 2019; Meshram et al., 2012; Motedayen, Dousti, Sayehmiri, & Pourmahmoudi, 2019; Musoke & Fergusson, 2011; Titaley, Ariawan, Hapsari, Muasyaroh, & Dibley, 2019) have addressed local and regional level, distribution and risk factors of malnutrition in literature, we found no published studies that had examined multilevel inter-connected contextual factors associated with SAM globally especially among SSA countries. In this study, we considered the central role of neighbourhoods in shaping tendencies of children to develop SAM. The goal of this study was to develop and test a model of risk factors associated with SAM among U5C in SSA countries using individual-level, neighbourhood- and country- level socio-economic factors.

Methods

Study design and data

We used sets of cross-sectional data obtained from Demographic and Health Surveys (DHS) for this study. The DHS data are nationally representative household surveys and are conducted in SSA countries. This study used data from 51 recent DHS surveys conducted between 2010 and 2018 and available as of March 2019 and that included under-five children (U5C) anthropometry data. Typically, the DHS uses a multi-stage, stratified sampling design with households as the sampling unit (Croft, Marshall, & Allen, 2018; ICF International, 2012). Country-specific sampling methodologies are also available at dhsprogram.com and also available in report forms (ICF International Inc., 2012; National Bureau of Statistics Tanzania and ICF - Macro, 2011; National Population Commission (Nigeria) and ICF International., 2014). Within each sampled household, all women and men meeting the eligibility criteria are interviewed. Sampling weights are calculated to account for unequal selection probabilities including non-response whose application makes survey findings represent the full target populations. All the DHS questionnaires are standardized and implemented across countries with similar interviewer training, supervision, and implementation protocols. In this study, we used the DHS children recode data. The data covered health experiences of under-five children born to sampled women within five years preceding the survey date. The anthropometry measurements were taken using standard procedures.

Dependent variable

Our dependent variable is severe acute malnutrition. It was a composite score of children weight and height. We generated z-scores using WHO-approved methodologies (WHO, 2009b) and categorized children with z-scores <3 standard deviation as having SAM.

Independent variables

There are three categories of explanatory variables

Individual-level factors: sex of the children (male versus female), children age in years (under 1 and 1-5 year), maternal age (15 to 24, 25 to 34, 35 to 49), maternal educational attainment (no education, primary, secondary or higher); marital status (never, currently and formerly married), occupation (working or not working), access to media, sources of drinking water (improved or unimproved), toilet type (improved or unimproved), weight at birth (average+, small and very small) birth interval (first born, <36 months and >36 months) and birth order (1, 2, 3 and 4+). We used the DHS wealth index as a proxy indicator for socioeconomic status. The methods used in computing DHS wealth index have been described previously(Vyass & Kumaranayake, 2006).

Neighbourhood-level factors

In this study, the term "neighbourhood" was used to describe clustering within the same geographical living environment. Neighbourhoods were based on sharing a common primary sample unit (PSU) within the DHS data. The PSUs were identified using the most recent census in each country where DHS was carried out. The neighbourhood-level factors included in the models are place of residence (rural or urban), neighbourhood poverty-, illiteracy- and unemployment rates. The neighbourhood factors were categorized into two (low and high) each, to allow for non-linear effects and offer useful results for policy decisions. The median values were used as the reference category for comparison.

Country-level factors

Country-level data were retrieved from the human index reports published by the United Nations database (United Nations, 2018; United Nations Development Programme, 2018b). In particular, we included countries' percentage rural population(United Nations, 2018) and the intensity of deprivation (United Nations Development Programme, 2018b). Both indicators belong to the body of the human development index (HDI). The HDI was created by the United Nations to emphasize "that people and their capabilities should be the ultimate criteria for assessing the development of a country, not economic growth alone" (United Nations Development Programme, 2018a). The HDI summarizes average achievement in long and healthy life, being knowledgeable and have a decent standard of living dimensions of human development(United Nations Development Programme, 2018a). The intensity of deprivation is a measure of the average percentage of deprivation experienced by people in multidimensional poverty while percentage rural population is a measure of the proportion of a countries population that resides in rural areas. The two factors were categorized into two (low and high) levels.

Statistical analyses

Descriptive statistics were used to show the distribution of respondents by country, dependent and independent variables in percentages. Chi-square test of association was used to determine the significance of the association between the independent variables and SAM (Table 1).

Modelling approaches

We used multivariable logistic multilevel regression models to analyse the association between individual compositional and contextual factors associated with SAM. Using the 3-level model for binary response specified above, with children who had SAM (at level 1), in a neighbourhood (at level 2) living in a country (at level 3) (see Fig. 2). To arrive at a robust model that will help identify risk factors of SAM bearing in mind the hierarchical structure of the data, we constructed five models. The first model, (Model 1- an empty model) without any explanatory variables, was specified to decompose the magnitude of variance that existed between country and neighbourhood levels. The Model II contained only individual-level factors, Model III has only neighbourhood-level factors, Model IV contained only the country-level factors while Model V ((Full Model) which jointly controlled for all the individual-, neighbourhood- and country-level factors. The multilevel regression model was executed in the MLwinN software, version 3.03(Charlton, Rasbash, Browne, Healy, & Cameron, 2018). Parameters were estimated using the Bayesian Markov Chain Monte Carlo (MCMC) procedures (Browne, 2019) with the following specifications: Distribution: binomial; link: logit, burning: 5000, chain: 50000 and refresh: 500.

Fixed effects (measures of association)

The results of fixed effects (measures of association) were reported as odds ratios (ORs) with their 95% credible intervals (CrIs). The Bayesian statistical inference provides an opportunity to summarize probability distributions for measures of association alongside the 95 % credible intervals (95 % CrI), rather than 95 % confidence intervals (95 % CI) obtained in the frequentist approach. A 95 % credible interval is easily interpreted as the 95 % probability that the parameter takes a value in a particular range.

Random effects (measures of variation)

We also measured the likely contextual effects of the factors considered in the different levels using the intraclass correlation (ICC) and median odds ratio (MOR). The ICC was used to measure the similarity between respondents in the same neighbourhood and within the same country. It estimates the percentage of the total variance in the probability of a child having SAM that is related to the neighbourhood and country-level, i.e. measure of clustering of odds of reporting cigarette smoking in the same neighbourhood and country. The ICC was calculated by the linear threshold (latent variable method)(Snijders & Bosker, 2012). Adopting the methods recommended by Larsen et. al. on neighbourhood effects(Larsen & Merlo, 2005), we reported the random effects in terms of the odds. The MORs are the measures of the variance of the odds ratio in higher levels (neighbourhood or country) and it estimates the probability of having SAM that can be attributed to any of the neighbourhood and country factors. If MOR=1, there is no neighbourhood or country variance. Conversely, the higher the MOR, the more significant are the contextual effects for understanding the probability of having SAM. A similar approach has been used in a similar setting in the literature (Uthman, 2016; Uthman et al., 2018).

Model fit and specifications

Multicollinearity among explanatory variables was checked by examining the variance inflation factor (VIF) (Tu, Kellett, Clerehugh, & Gilthorpe, 2005). All diagonal elements in the variance-covariance (τ) matrix for correlation between −1 and 1, and diagonal elements for any elements close to zero. None of the results of the tests provided reasons for concern. Thus, the models provide robust and valid results. The Bayesian Deviance Information Criterion (DIC) was used to evaluate how well the different models considered in this study fitted the data. A lower value on DIC indicates a better fit of the model.

Results

Sample characteristics

The regions of the world, countries, year of data collection, numbers of neighbourhoods, number of under-five children and the weighted prevalence of SAM are listed in Table 1. A total of 33 SSA countries were sampled with the surveys conducted between 2010 and 2018. For this analysis, we analysed information on 210,289 under-five children (Level 1) nested within 17,529 neighbourhoods (Level 2) from 33 SSA countries (Level 3). The median number of neighbourhoods per country sampled was 531, ranging from 251 in Comoros to 1,592 in KenyaIndia. The overall SAM prevalence was 3.0% with a median prevalence of 2.6% ranging from 0.5% in South Africa to 8.8% in Nigeria as shown in Table 1 and Figure 1.

Table 1: Description of Demographic and Health Surveys data by countries and SAM prevalence among under-five children in SSA countries, 2010-2018

Country	Year of Survey	Number of Neighbourhoods	Number of Under-5 Children	Weighted SAM prevalence
All		17,529	210,289	3.0
Eastern Africa		6,283	67,418	1.5
Burundi	2016	554	6,052	0.9
Comoro	2012	251	2,387	3.9
Ethiopia	2016	640	8,919	3.0
Kenya	2014	1,592	18,656	1.0
Malawi	2016	850	5,178	0.6
Mozambique	2011	610	9,313	2.1
Rwanda	2015	491	3,538	0.6
Tanzania	2016	607	8,962	1.3
Uganda	2016	688	4,413	1.4
Middle Africa		3,071	37,136	2.5
Angola	2016	625	6,407	1.0
Cameroon	2010	575	5,033	1.9
Chad	2015	623	9,826	4.3
Congo	2012	384	4,475	1.6
DRC	2014	536	8,059	2.7
Gabon	2012	328	3,336	1.2
Southern Africa		2,441	20,273	1.7
Lesotho	2016	369	1,312	0.7
Namibia	2013	486	1,558	2.2
South Africa	2016	466	1,082	0.5
Zambia	2014	721	11,407	2.1
Zimbabwe	2015	399	4,914	1.1
Western Africa		5,734	85,462	4.7
Benin	2018	555	12,033	1.1
Burkina Faso	2010	572	6,532	5.8
Cote d'Ivoire	2012	350	3,200	1.8
Gambia	2013	276	3,098	4.7
Ghana	2014	418	2,720	0.7
Guinea	2012	300	3,085	3.7
Liberia	2013	322	3,171	2.2
Mali	2013	412	4,306	5.1
Niger	2012	476	4,771	6.2
Nigeria	2013	895	24,505	8.8
Senegal	2017	400	10,787	1.5
Sierra Leone	2013	430	4,069	3.8
Togo	2014	328	3,185	1.6

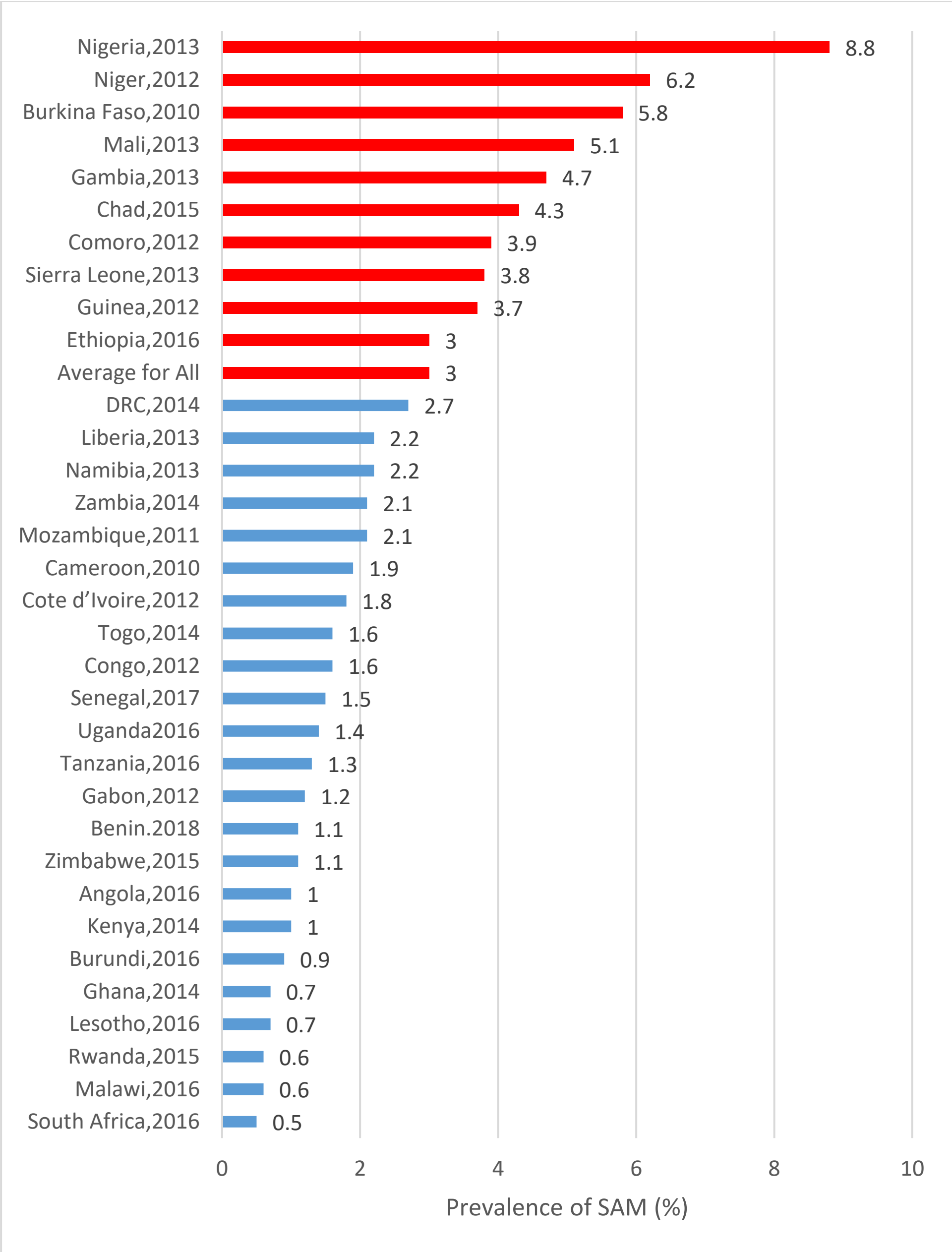

Figure 1: Distribution of SAM in SSA countries

In Table 2, we present the descriptive statistics for the pooled sample. One-fifth of the children were infants, more than half of the respondents were male (51 %) and the majority of their mothers were between the 25 and 34 years of age (53 %). Nearly a third (31 %) of their mothers had no formal education while only 16 % belong to households in the richest wealth quintiles. Most of their mothers were currently employed (71 %) and currently married (9481 %). Most (81 %) of the children had drinking water from improved sources but only 50 % had improved toilet types. Most of the children were living in rural areas (69 %), high poverty rate (21 %), high illiteracy rate (29 %), and high unemployment rate (27 %) neighbourhoods. At the country level, 27% lived in countries with a high level of intensity of deprivation and 81% in high percent rural population. All the variables considered at the different levels were significantly associated with SAM at 5% chi-square test. Also, the bivariate logistics regression models between each of the explanatory variables and SAM showed that all the variables significantly predicted SAM at p=0.05. Hence, they are all suitable for inclusion in the multivariable models.

Table 2: Description of Demographic and Health Surveys data by background characteristics and SAM prevalence among under-five children in SSA countries, 2010-2018

Characteristics	Weighted %	Weighted SAM prevalence	Pearson X^2 test p-value
Individual Level			
Age			
<12 Months	20.0	7.4	<0.0001
12 - 59 Months	80.0	4.0	
Sex			
Female	48.8	4.3	<0.0001
Male	51.2	5.1	
Maternal Age			
15-24	31.0	5.2	<0.0001
25-34	52.9	4.6	
35-49	16.1	3.8	
Maternal Education			
No Education	31.1	5.8	<0.0001
Primary	25.3	3.1	
Secondary	43.6	4.8	
Wealth Index			
Poorest	23.8	5.6	<0.0001
Poorer	21.8	4.8	
Middle	20.1	4.5	
Richer	18.7	4.2	
Richest	15.5	3.8	
Employment			
Yes	70.8	5.0	<0.0001
No	29.2	3.9	
Access To Media			
No	36.5	5.3	<0.0001
Yes	63.5	4.3	
Drinking Water			
Unimproved	19.2	4.1	<0.0001
Improved	80.8	4.8	
Toilet Type			
Unimproved	49.9	5.2	<0.0001
Improved	50.1	4.1	
Marital Status			
Never Married	2.4	1.9	<0.0001
Currently Married	93.8	4.8	
Formerly Married	3.9	2.4	
Weight At Birth			
Average+	85.4	4.6	<0.0001
Small	10.7	5.0	
Very Small	4.0	6.4	
Birth Interval			
1st	30.4	4.8	<0.0001
<36	37.4	4.9	
36+	32.1	4.2	
Birth Order			
1	30.4	4.8	<0.0001
2	26.0	4.9	

3	16.1	4.6	
4	27.6	4.3	
Neighbourhood factors			
Place of residence			
Urban	30.7	4.2	<0.0001
Rural	69.3	4.9	
Poverty rate			
Low	79.0	4.4	<0.0001
High	21.0	5.7	
Illiteracy rate			
Low	70.7	4.2	<0.0001
High	29.3	5.9	
Unemployment rate			
Low	72.6	5.0	<0.0001
High	27.4	3.8	
Community SES Quintiles			
1 (Highest)	20.2	4.2	<0.0001
2	20.0	4.3	
3	20.1	4.2	
4	20.0	5.0	
5 (Lowest)	19.7	5.8	
Country-level			
Intensity of Deprivation			
Low	73.0	5.0	<0.0001
High	27.0	3.8	
Percent Rural Population			
Low	18.6	3.0	<0.0001
High	81.4	5.1	
Multidimensional Poverty Index			
Low	74.7	5.7	<0.0001
High	25.3	1.8	
Total	100.0	4.7	

Further Multivariable Analysis is ongoing

Discussion

Since the WHO declared war against SAM, there is a paucity of information on the relationship between contextual and societal factors in the distribution of SAM among under-five children. The current study appeared to have been the first multilevel examination of factors associated with SAM across the globe wherein we considered 33 SSA countries using national representative data consisting of 210,289 children found in 17,529 neighbourhoods.

Conclusions

In conclusion, at 3.0 % prevalence, over twelve million under-five children in the SSA countries have SAM. Individual compositional and contextual measures of socioeconomic position were independently associated with the having SAM across the 33 SSA countries. These findings underscore the need to revitalize existing policies and implement interventions to rescue and stop children from having SAM at the individual-, community- and societal-levels.

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