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Analyzing Child Malnutrition in Bangladesh: Generalized Linear Mixed Model Approach

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Abstract

Child malnutrition is a serious issue for overall child health and future development. Stunting is a key anthropometric indicator of child malnutrition. Because of the nature of sampling design used in Bangladesh Demographic Health Survey, 2011, responses obtained from children under same family might be correlated. Again, children residing in same cluster may also be correlated. To tackle this problem, generalized linear mixed model (GLMM), instead of usual fixed effect logistic regression model, has been utilized in this paper to find out potential factors affecting child malnutrition. Model performances have also been compared.

Keywords: Child malnutrition, Generalized linear mixed model, Intra-cluster correlation, Stunting.

I. Introduction

Malnutrition is a severe problem in under developed and developing countries. Malnutrition directly affects mortality rate since lack of nutrition leads to disease and ultimately death. Malnutrition in children is common globally and results in both short and long term irreversible negative health outcomes including stunted growth which may also be linked to cognitive development deficits, underweight and wasting[1]. The World Health Organization (WHO) estimates that malnutrition accounts for 54 percent[2] of child mortality worldwide, about 1 million children. Common causes of malnutrition are high food price and low access to nutritious food items. Poor feeding practices, such as inadequate breastfeeding, offering the wrong foods, and not ensuring that the child gets enough nutritious food, contribute to malnutrition. Infection – particularly frequent or persistent diarrhea, pneumonia, measles and malaria – also undermines a child's nutritional status. Malnutrition passes from one generation to the next because malnourished mothers give birth to malnourished infants. If they are girls, these children often become malnourished mothers themselves, and the vicious cycle continues. Over the years Bangladesh has made substantial progress in terms of reducing malnutrition. Note that, stunting, wasting and underweight are the three indicators of child malnutrition. Among these, stunting is widely used because effects of stunting are irreversible. The level of child stunting decreased from 66% to 49% between 1990 and 2004[3]. Nevertheless, prevalence rates of child stunting and underweight children are still "very high" according to criteria including those set by the WHO. Despite Bangladesh's achievement in reducing under-5 mortality, chronic stunting is still in an alarming state with 41%[4] under-5 children stunted in 2011. High level of stunting indicates poor social-economic condition and it might increase the risk of frequent or early exposure to illness. These stunted children face great difficulties in their life, burdened with diseases, low productivity and lower performance in every aspect of life. On the other hand, decrease in the stunting rate indicates overall socio-economic improvement of a country. Therefore, identifying the factors associated with child stunting is of interest to public and population health research.

Bangladesh Demographic and Health Survey[4] provides nationally representative data on maternal and child health. The sampling design used in BDHS, 2011 survey was two stage stratified cluster sampling. Under this set up, data on children obtained from same mother or same cluster are likely to be correlated. Therefore, to obtain consistent and efficient estimates of parameters of interest, it is required to take this correlation into account at the stage of estimation. To model such correlated data, generalized linear mixed model (GLMM)[5] can be used. Since data on children can be considered clustered within families (mothers) and clustered within sampling clusters, two different mixed models have been considered in this paper. Siblings might be correlated because they belong to same family and mother. Thus, they share some unobserved characteristics in some aspects such as heredity, caring, values and belief. Again, there are 600 clusters randomly chosen with probability proportional to the size. Children residing within a cluster might have some level of correlation among them because of some unobserved characteristics such as community effect, geographic effect and policy implementation. Handling these correlation and unobserved aspects require more sophisticated statistical model than usual fixed effect regression model. GLMM is one of the approaches taken for accounting for these effects.

In this paper, the malnutrition status of a child has been indicated through stunting of a child. If a child is stunted, he/she is considered malnourished. GLMMs for this binary responses are fitted under two settings: (i) In Model I (Family level), random effect component has been introduced for each family and (ii) in Model II (Cluster level), random effect component has been introduced for each cluster. It is assumed that the baseline odds of having the event is same for the children under each family in Model I and under each cluster in Model II. It is also assumed that odds varies from family to family in Model I and cluster to cluster in Model II.

II. Methodology

Generalized linear model (GLM) is unable to handle correlation in clustered data. To accommodate it into the model, GLM has been extended to generalized linear mixed model (GLMM)[6,7], which includes random effect component

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along with fixed effects. Mixed models for continuous normal outcomes have been extensively developed since the seminal paper by Laird and Ware in 1982[8]. Following this model, generalized linear model is extended by including random effect term along with explanatory variables in the linear predictor[8] for non-normal responses.

Let Y_{ij} be the binary response collected from the j^{th} individual in the i^{th} cluster; $j = 1, \cdots, n_i$ and $i = 1, \cdots k$. Suppose that $x_{ij} = (x_{ij1}, \cdots, x_{ijr}, \cdots, x_{ijp})'$ is the $p \times 1$ vector of covariates for the j^{th} individual in the i^{th} cluster and $\beta = (\beta_1, \cdots, \beta_r, \cdots, \beta_p)'$ is the $p \times 1$ vector of regression coefficients for the corresponding p covariates. The random effect term for the i^{th} cluster, u_i is assumed to be normally distributed with zero mean and variance σ_u^2. The GLMM for binary response for the j^{th} individual in the i^{th} cluster can be written as

$$g(\mu_{ij}^*) = \ln \mu_{ij}^* (1 - \mu_{ij}^*)^{-1} = x_{ij}'\beta + u_i = \eta_{ij},$$

where $\mu_{ij}^* = E(Y_{ij}|u_i) = [1 + \exp(-x_{ij}'\beta - u_i)]^{-1}$. In other words, the conditional distribution of Y_{ij} is Bernoulli with mean μ_{ij}^* and variance $\mu_{ij}^*(1 - \mu_{ij}^*)$. Under this setup, the main parameter of interest is the regression parameter β and the variance component σ_u^2 is considered as a nuisance parameter. The conditional likelihood function for GLMM can be written as

$$L(\beta, \sigma_u^2 | x_{ij}, u_i) = \prod_{i=1}^{k} \prod_{j=1}^{n_i} f(y_{ij}|x_{ij}, u_i).$$

Hence, the marginal likelihood function can be obtained by integrating out the random effect, i.e. the marginal likelihood function is

$$L(\beta, \sigma_u^2) = \int_{-\infty}^{\infty} \left[\prod_{i=1}^{k} \prod_{j=1}^{n_i} f(y_{ij}|x_{ij}, u_i) \right] du_i.$$

The maximum likelihood estimators for β and σ_u^2 can be obtained by maximizing the marginal likelihood function. In this paper, STATA 13 command *xtmelogit*, has been utilized for the estimation.

Under GLMM setup, correlation among the responses within same cluster is usually known as intra-cluster correlation. This correlation coefficient, denoted by ρ, can be expressed as a function variance[9] component as $\rho = \sigma_u^2 \left(\sigma_u^2 + \frac{\pi^2}{3} \right)^{-1}$.

III. Data and Variables

Data for analyzing child malnutrition were obtained from Bangladesh Demographic and Health Survey (BDHS), 2011. BDHS 2011 utilized a two stage stratified cluster sampling design, yielding information on 18,000 ever-married women and their children. Only live births during the last 5 years before the survey date were retained, resulting information on total 8913 children from 7423 unique mothers. This process ensures that analysis was performed on most recent data and reduces misinformation and reporting errors. Among these 7423 mothers 6036 (81.31%) had only one child, 1291 (17.39%) had two children, 89 (1.20%) had three children and 7 (0.09%) had four children. Therefore, there are total 1387 (18.69%) mothers with repeated responses. The primary variable of interest, in this paper, is stunting of child less than five years of age. Stunting is the height-to-age ratio which indicates if a child has failed to achieve the height proportional to his/her age. A child is termed stunted if he/she falls behind two standard deviations from median height-to-weight ratio. Key social, demographic and health factors associated with child stunting were identified in the literature[3,10,11]. The selected covariates are: division, type of residence, wealth, mother's education, mother's age at birth, NGO membership, exposure to media, sex of child, birth order, delivery place, size at birth and delivery by cesarean section.

The sample consists of subjects :11% from Barsial, 20% from Chittagong, 16.5% from Dhaka, 11% from Khulna, 12% from Rajshahi, 13% from Rangpur and 16% from Sylhet with 30.6% living in urban areas and other 69.4% in rural areas. 41.7% individuals were from poor families, 19% from middle income families and rest of 39.3% from rich households. The mothers considered in this analysis had average age of 25.61 (±5.92) years. About 76 percent of them got married before reaching age 18 years. The average age at marriage was found to be 15.93 (±2.84) years. About 28 percent of the mothers had their children before 20 years of age. Among these mothers 19.4% had no education, 30.7% received primary education, 29.2% completed secondary education and only 13.5% completed higher education. 26% of them held NGO membership and 63.7% had some exposure to media. 51.4% of the live birth occurred were male, 48.6% were female. 14.6% of these births were via cesarean section. 17.6% of the births were small in size. 27.4% of the deliveries happened in home. Among the alive children, 41 percent of them were stunted. This indicates these children failed to attain the height according to their age. Globally this rate is 25 percent in 2012 which implies, in Bangladesh children are suffering malnutrition more than other parts of the world.

IV. Results

To examine the association of selected covariates with stunting, a bivariate analysis has been conducted using Pearson's chi square test. It has been found that all of the variables considered are significantly (p-value<0.05) associated with child stunting except for the sex of child. The highest rate of stunting has been observed in Sylhet (47.42%) and the lowest has been found for Rajshahi (32.53%). Children living in the rural areas found to be more stunted (43.28%) compared to urban areas. Stunting rate reduced with the wealth. 51.50% of the poor children suffered from stunting where 40.66% of the middle class and only 29.66% of the rich children were stunted. Lower educated mothers had more children stunted (52.73%) than educated mothers (for primary 46.70%, secondary 35.18% and higher 20.56%). Mothers with NGO membership had

44% of their children stunted compared to 39.70% for mothers without any membership. Mothers with no exposure had 50.31% of their children stunted where this rate is 35.57% for mothers with media exposure. 43.47% children were stunted for whom the age of their mother at their birth were below 20 years.

Table 1. Odds ratios, 95% confidence intervals and p-values obtained from GLMMs for child stunting.

Variables	Model I (Family)				Model II (Cluster)			
	Odds ratio	P-value	95% CI		Odds ratio	P-value	95% CI	
Division								
Barisal	-	-	-	-	-	-	-	-
Chittagong	1.021	0.847	1.262	1.489	1.017	0.874	0.825	1.254
Dhaka	1.124	0.293	0.904	1.398	1.115	0.318	0.901	1.379
Khulna	0.796	0.061	0.627	1.010	0.813	0.079	0.645	1.024
Rajshahi	0.628	0.000	0.494	0.799	0.673	0.001	0.534	0.848
Rangpur	0.935	0.565	0.745	1.174	0.946	0.622	0.757	1.181
Sylhet	1.242	0.114	0.994	1.552	1.205	0.098	0.966	1.501
Type of residence								
Rural	-	-	-	-	-	-	-	-
Urban	1.129	0.085	0.984	1.297	1.103	0.151	0.965	1.261
Wealth								
Poor	-	-	-	-	-	-	-	-
Middle	0.735	0.000	0.625	0.863	0.765	0.000	0.666	0.879
Rich	0.506	0.000	0.427	0.601	0.550	0.000	0.476	0.636
Mother's education								
No education	-	-	-	-	-	-	-	-
Primary	0.871	0.107	0.737	1.030	0.897	0.142	0.777	1.037
Secondary	0.669	0.000	0.558	0.801	0.724	0.000	0.620	0.845
Higher	0.452	0.000	0.334	0.613	0.513	0.000	0.393	0.668
NGO membership								
No	-	-	-	-	-	-	-	-
Yes	1.056	0.409	0.927	1.203	1.056	0.344	0.943	1.184
Exposure to media								
No	-	-	-	-	-	-	-	-
Yes	0.831	0.008	0.725	0.953	0.858	0.011	0.762	0.966
Age at each birth								
<20 years	-	-	-	-	-	-	-	-
20-35 years	0.741	0.000	0.633	0.868	0.773	0.000	0.674	0.887
35+ years	0.675	0.008	0.504	0.903	0.710	0.008	0.551	0.915
Sex of child								
Female	-	-	-	-	-	-	-	-
Male	0.982	0.750	0.880	1.096	0.986	0.779	0.895	1.087
Delivery place								
Hospital	-	-	-	-	-	-	-	-
Home	1.321	0.003	1.098	1.590	1.274	0.004	1.082	1.500
Size at birth								
Small	-	-	-	-	-	-	-	-
Medium/Large	0.587	0.000	0.505	0.682	0.616	0.000	0.542	0.700
Birth order								
First	-	-	-	-	-	-	-	-
More than one	1.175	0.035	1.011	1.366	1.171	0.020	1.025	1.338
Cesarean delivery								
No	-	-	-	-	-	-	-	-
Yes	0.947	0.644	0.753	1.191	0.975	0.808	-.796	1.195
Log-likelihood	- 4616.1301				- 4632.9791			
Variance component	0.892				0.320			

This rate is 39.48% and 44.63% for the mothers with age at marriage between 20 to 30 years and above 35 years respectively. Rate of stunting for female and male children were 41.23% and 40.49% respectively. First born children were less stunted (37.21%) than children with higher birth order (42.83%). Children delivered at home were more stunted (45.29%) than children delivered at hospitals/clinics (28.96%). 51.23% children were stunted who were born in small size and 38.74% were stunted who were born in medium/large size. 26.88% cesarean babies were stunted compared to 43.31% normally delivered babies.

In the adjusted analysis, generalized linear mixed models have been fitted for child stunting considering two types of correlations: family level and cluster level. From the estimated parameters, after adjusting for other covariates, odds ratios for covariates have been computed and interpreted and p-value less than 0.05 has been considered as an indication of statistically significant association. Odds ratios along with 95% confidence interval and p-values have been reported in the Table 1. Out of twelve covariates, eight were detected as significant factors associated with child stunting. These are: division, wealth, mother's education, exposure to media, mother's age at each birth, place of delivery, birth order and size at birth. Effects of type of residence, NGO membership, sex of child, cesarean delivery were not found significant in the GLMM. Divisional effect on child stunting has been compared taking Barisal as a reference. Child stunting situation in Sylhet has appeared to be the worst with 20.5% (Model II) and 24% (Model I) higher odds of being stunted compared to Barisal. About 32% (Model II) odds of being stunted is observed in Rajshahi which has the lowest stunting rate. Only for Rajshahi the difference in stunting situation has been found statistically significant. Wealth index is a statistically significant factor related to stunting. Improvement of economic status improves child nutrition level thus resulting in lower number of stunted children. In relation to poor families, middle class and rich families have 23.5% (Model II) and 26.5% (Model I); and 45% (Model II) to 49.4% (Model I) lower odds of having stunted children respectively. The more educated the mother, her children healthier. Mothers with secondary education, have their children 27.6% (Model II) and 33.1% (Model I) less stunted than mothers with no education. Mothers with higher education, have their children 48.7% (Model II) and 54.8% (Model I) less stunted than mothers with no education. But this effect of education is not significant for women with primary education. Mothers having child between 20 to 35 years have significantly lower risk of child stunting. Mothers with age 35 years above when having children also have significantly lower odds of stunting of their children. Children born to mothers with age less than 20 years faced highest risk of stunting compared to mothers having children after 20 years. Thus age of mother at the birth of child has a significant effect on child stunting. Exposure to media tends to improve the level of stunting with lower odds of children being stunted. Children who were born in home are at 27.4% (Model II) and 32.1% (Model I) higher risk of stunting than children who were born in hospital/clinic or other facility. First born children face lower chance of being stunted than those are born later. Children with birth order greater than one has around higher odds of being stunted than children with birth order one. In addition, size at birth is an important factor for child nutrition. Babies born with size medium or large have about 38.4% (Model II) and 41.3% (Model I) lower odds of being stunted than babies who are born with small size. Size of child is related to nutrition status of mother in the pregnancy stage. Size of baby at birth has significant effect on child stunting.

V. Discussion

Traditional logistic regression model is not appropriate to analyze the clustered data, because responses from the same cluster are not independent, though clusters are independent. To take the dependency into account one needs to consider a generalized linear mixed model to obtain consistent as well as efficient estimators for the regression parameters of interest. In this paper, an attempt has been made to find potential factors for child stunting using clustered data extracted from BDHS, 2011. For this purpose, GLMM for binary response has been used.

The performance of GLMMs has been compared with usual logistic regression model using clustered data. Likelihood ratio tests indicate that both the mixed models (Model I and Model II) perform significantly better than the fixed effect model as p-values were found to be <0.000. Therefore, the use of GLMMs has been justified. Secondly, Model I and Model II were compared for finding out which one explains better variation and tackles correlations. It was found that intra-cluster correlations obtained from Model I and Model II were 0.213 and 0.089, respectively. Thus family level model explains more correlation in the data. The fitted mixed models can be compared using Akaike Information Criterion (AIC), which is given as AIC= 2(Number of parameters estimated - log-likelihood). For Model I and Model II, AIC values were 9794.330 and 9792.402, respectively. There exists very slight difference in AIC values and lowest for model II. Therefore, Model II seems to be a better fit. But the intra-cluster correlations suggest that there is a considerable correlation among siblings compared to the children under same cluster. Therefore, Model I addresses an important aspect of the correlated data.

From Model I it is clear that improvement in mother's education and economic status lead to better nutrition status of children by reducing child stunting rate. Stunting has not been found varying across divisions though the children of Rajshahi had significantly lower odds of being stunted compared to Barisal. From this analysis, it can be recommended mothers will conceive between age 20 years and 35 years for the growth of their children. Since size of the baby at birth highly depends on the nutrition status of the pregnant mother, mother's nutrition status during the pregnancy period should be kept in attention. In addition, children should be delivered at hospital/clinic instead of home. Nutrition for children born after the first child must be ensured since they seem to be more affected by stunting. Access to media like newspaper, radio or television was also found important factor for reducing stunting. Therefore, mother should be encouraged to read newspaper, listen to radio or watch television.

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