Italian Journal of Pediatrics

Prevalence of Stunting and Associated Factors among under-5 children in Bangladesh: An Application of Multilevel Mixed-effects Logistic Regression Model.

--Manuscript Draft--

Manuscript Number:	
Full Title:	Prevalence of Stunting and Associated Factors among under-5 children in Bangladesh: An Application of Multilevel Mixed-effects Logistic Regression Model.
Article Type:	Research
Section/Category:	Pediatric Gastroenterology and Nutrition
Funding Information:	
Abstract:	Background One of the most well-established risk indicators of poor child development is stunting. Although several studies were conducted on this issue, extensive analyses are still required in developing countries to understand stunting. We sought to evaluate the prevalence of stunting in children under the age of five, and the associated factors using a multilevel mixed-effects logistic regression model. Methods We used a nationally representative data from the Bangladesh Demographic and Health Survey (BDHS) 2017-18. We conducted a multivariable binary logistic regression model and then multilevel mixed-effects logistic regression to determine the risk factors of child stunting at single-level and multilevel, respectively. Result About 30.48% of children were found to be stunted in Bangladesh. We found that most of the stunted children (38.54%) were found in poor family settings in Bangladesh, and the rate of stunting was mainly higher in rural areas (32%). The most vulnerable age group (24-35) months children had found 3.03 times (OR: 3.03, 95% CI: 2.42- 3.80) higher chance of stunting in multilevel multivariable binary logistic regression model., Furthermore, division, parents' education level, household head's occupation, and wealth index were significantly associated with stunting. Conclusion The prevalence of stunting is still very high in Bangladesh. Child stunting was significant at both individual and regional levels. Most importantly, although Bangladesh achieved a good literacy level, educated parents are playing a vital role in reducing child malnutrition. Therefore, policymakers should take proper steps to increase the literacy rate as much as possible. Keywords Stunting, Multilevel Mixed-effects, under-five children, Associated factors, Model Comparison, Bangladesh.
Corresponding Author:	Md Jamal Uddin Shahjalal University of Science and Technology BANGLADESH
Corresponding Author E-Mail:	jamal-sta@sust.edu
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Shahjalal University of Science and Technology

Corresponding Author's Secondary Institution:	
First Author:	Afrida Nower Mowmi
First Author Secondary Information:	
Order of Authors:	Afrida Nower Mowmi
	Syed Toukir Ahmed Noor
	Mohammad Nayeem Hasan
	Muhammad Abdul Baker Chowdhury
	Md Jamal Uddin
Order of Authors Secondary Information:	
Additional Information:	
Question	**Response**
Is this study a clinical trial?<hr><i>A clinical trial is defined by the World Health Organisation as 'any research study that prospectively assigns human participants or groups of humans to one or more health-related interventions to evaluate the effects on health outcomes'.</i>	No

Prevalence of Stunting and Associated Factors among under-5 children in Bangladesh: An Application of Multilevel Mixed-effects Logistic Regression Model

Afrida Nower Mowmi[1], Syed Toukir Ahmed Noor[1], Mohammad Nayeem Hasan[1], Muhammad Abdul Baker Chowdhury[2], Md Jamal Uddin[1,3,*]

[1]Department of Statistics, Shahjalal University of Science & Technology, Sylhet-3114, Bangladesh

[2]Department of Neurosurgery, University of Florida College of Medicine, Gainesville, FL, USA.
[3]Department of General Educational and Development, Daffodil International University, Dhaka, Bangladesh
*Corresponding Author

Abstract

Background: One of the most well-established risk indicators of poor child development is stunting. Although several studies were conducted on this issue, extensive analyses are still required in developing countries to understand stunting. We sought to evaluate the prevalence of stunting in children under the age of five, and the associated factors using a multilevel mixed-effects logistic regression model.

Methods: We used a nationally representative data from the Bangladesh Demographic and Health Survey (BDHS) 2017-18. We conducted a multivariable binary logistic regression model and then multilevel mixed-effects logistic regression to determine the risk factors of child stunting at single-level and multilevel, respectively.

Result: About 30.48% of children were found to be stunted in Bangladesh. We found that most of the stunted children (38.54%) were found in poor family settings in Bangladesh, and the rate of stunting was mainly higher in rural areas (32%). The most vulnerable age group (24-35) months children had found 3.03 times (OR: 3.03, 95% CI: 2.42- 3.80) higher chance of stunting in multilevel multivariable binary logistic regression model., Furthermore, division, parents' education level, household head's occupation, and wealth index were significantly associated with stunting.

Conclusion: The prevalence of stunting is still very high in Bangladesh. Child stunting was significant at both individual and regional levels. Most importantly, although Bangladesh achieved a good literacy level, educated parents are playing a vital role in reducing child malnutrition. Therefore, policymakers should take proper steps to increase the literacy rate as much as possible.

Keywords: Stunting, Multilevel Mixed-effects, under-five children, Associated factors, Model Comparison, Bangladesh.

Introduction

Stunting is one of the most well-established risk factors for poor child development. Globally, 149.2 million under-five children (22.0%) were suffering from stunting in 2020 [1]. In Africa, 58.7 million children under the age of five are stunted. It is responsible for 39 percent of stunted children under the age of five across the world [33] Furthermore, the recent Southern Asia is 30.7 percent, which is greater than the global norm of 22.0 percent.[6] In Bangladesh, nearly 41% of children under five years old were stunted in 2017 and a higher proportion of stunted children (42.54%) were detected in rural areas [3].There is an worldwide goal to reduce the number of under-five stunted children from 171 million in 2010 to about 100 million in 2025, however; at the existing however at current rate it will most likely be 127 million stunted children by 2025 [2].. Bangladesh has undergone rapid urbanization in recent years, and it is predicted that there will be 50% more urban population by 2050 [8]. Bangladesh has also set an example of reducing child stunting in the last decade though it is very small. The prevalence is extremely concentrated on characteristics such as wealth index, exposure of the mother to the mass media, age of the child, size of child at birth, and parents' education in this area [9].Research other than Bangladesh shows that educated parents are better at taking care of their children than uneducated ones[10].In that case, child stunting is an outcome of long-term chronic intake of a low-quality diet (which leads to malnutrition) in combination with morbidity, contagious diseases, and environmental problems[10]. Consumption of food with insufficient calories and fewer than four different food groups consumed by children per day are key predictors of malnutrition [11] Past studies in Southwest Nigeria have shown that low maternal body mass index, low standard of living score, lower mental capacity, differential nutritional consumption, socioeconomic and cultural variation, differences in their genetic potential and less productivity are the consequences of overall stunting. These are severely linked with poverty, female literacy, nuclear family, gross product, and region of living [7,9,12, 13].

Moreover, the fundamental causes of having stunting among under-five children are multifactored such as low income, less than two meals per day, being female sex, father's occupation, maternal and paternal education, polygamous family settings, and exclusive breastfeeding, ethnic minority [11,12,14,15]. So, these factors initially set a barrier to the children from their childhood to grow properly in height and be productive in the future which also impedes the socio-economic development of a country. The factors which are actively maximizing the risk of stunting among school-going adolescents are gender discrimination, age, types of meals, mother's education, sources of drinking water, menstruation status, cold or cough, and diarrhea [5,11]. Therefore, reducing the risk of factors that are associated with stunting, limiting the number of pregnancies, and prevention of diarrheal diseases have received sudden attention from the improvement partners and have been considered as future development goals in this field [3,9,16].area (reduce

The study on the prevalence of stunting and its associated factors has been already covered by many countries' contexts. These studies vary from each other based on methodology, data collection procedure, analysis, study sites, and participants. As far as, in our knowledge, it is the first study in Bangladesh that is conducted by using multilevel logistic regression approach on last updated data from the Bangladesh Demographic and Health Survey (BDHS) 2017-18 to identify the prevalence of stunting and its associated risk factors.

Furthermore, the BDHS 2017-18 sample was a stratified cluster and was chosen in two steps. Correlation among the observations is frequently introduced by this stratified cluster sampling strategy, which might have an impact on multilevel binary model parameter estimates. In that case, the multilevel statistical approach has additional benefits over the classical one. The dependency among observations in multistage clustered samples derives from multiple levels of the hierarchy. Single-level statistical models are no longer appropriate in this circumstance. As a result, we may need to use techniques like multilevel modeling to derive suitable inferences.

According to some previous research, we found that they have data that has the same structure as BDHS but didn't consider the multilevel modeling approach[3,5,18,19].

Our study aims to find the factors of stunting among under-five children using the multilevel logistic regression model. So, the outcome of this study will help the stakeholders, health-related policymakers, and public health researchers to understand the current situation of stunting in Bangladesh, which may help take further actions and interventions to improve this condition [20].

Methodology

Data source and sampling technique:

This study relied on secondary data, which was gathered from the Bangladesh Demographic and Health Survey (BDHS) 2017-18. The BDHS data is available for all and can be accessed upon request (The DHS Program - Available Datasets).

The 2017-18 BDHS sample is nationally representative, covering the whole population of non-institutional housing units across the country. As a sample frame, the Bangladesh Bureau of Statistics (BBS) supplied a record of enumeration areas (EAs) from the 2011 People's Republic of Bangladesh Population and Housing Census (BBS 2011). About 120 households were surveyed on average in an EA as the primary sampling unit (PSU).

A two-stage stratified sample of households was conducted in this survey. In the first stage, 675 EAs were chosen with a probability proportional to EA size (250 in urban regions and 425 in rural areas). To produce a sampling frame for the second-stage selection of households, a comprehensive household listing operation was carried out in all selected EAs. On average, 30 households per EA were chosen in a systematic sample to produce statistically credible estimates of key demographic and health indicators for the nation, for urban and rural regions individually, and each of the eight administrative divisions in the second stage. Initially, 20,250 residential households were selected and expected to interview about 20,100 ever-married women aged 15-49. At last, 20,160 households were selected for the survey in total, the survey was successfully carried out in 672 clusters, after eliminating three clusters (one urban and two rural).

Study variables and measurements

Outcome variable: The status of child stunting is our outcome variable. We classified children under the age of five as not stunted if their height-for-age Z-score was less than -2 SD from the WHO child growth reference, and as not stunted if their height-for-age Z-score was greater than -2 SD. In this study, our response variable is a dichotomous variable where category 0 of not stunted, and category 1 is for the stunted child.

Independent variables: In accordance with the study's goals and because of the BDHS data's hierarchical structure, two-level independent variables were considered. They are individual level or first level variables and regional level or second level variables. We classified individual levels of independent variables in different groups such as socio-economic, demographic factors, and child-related factors.

The socio-economic and demographic factors are mother age (15-19, 20-24,25+), father age (≥24, 25-29,30-34,35+), fathers' and mothers' educational level (no education, primary, secondary, or higher) , household heads' occupation (jobless, farmer, agriculture, business, others), mother's work status (yes, no), wealth index (poor, middle, rich), religion (Islam, others), mothers' exposure to the mass media(yes, no), antenatal care (≥4, <4), type of toilet facility (modern toilet. others), place of delivery (Home, health facility), no. of household members (≥3, <3), household head's sex (male, female).

Child-related factors contain the age of the child (0-11, 12-23, 24-35, 36-47, and 48-59 months), the child's sex (male, female), a recent history of diarrhea (yes, no), a recent history of cough (yes, no), a recent history of fever (yes, no), c-section (yes, no), birth order (1-3,4-6,7-10)., size of the baby at birth. On the other hand, division and area of residence (urban, rural) are regional levels or secondary level independent variables. Detailed information on these variables can be found in **Table-1**.

Data management and analysis

This dataset was cleaned, recoded, and analyzed according to the DHS guide 7 using Stata version 14.0 and weighted using sampling weight. To adjust the complex survey design primary sampling units, and strata are considered before any statistical analyses were done to restore the representativeness of the survey. To perform a survey representative multilevel mixed-effects logistic regression model in Stata we need to follow a methodological report of DHS [21]. We used the Svyset command in Stata (StataCorp LP, College Station, Texas) by considering the complex survey design.

Firstly, we conducted a bivariate exploratory data analysis (EDA) to reveal the distribution of sampled respondents with child stunting and reported the outcome in frequency along with individual row percentage. The bivariate analysis was performed to understand the situation of child stunting among the individual level and regional level independent variables. After EDA, we performed a univariate binary logistic regression model (as our outcome variable is dichotomous) in which each variable at the individual and regional level as an independent variable. After that, to identify the risk factors of child stunting at a single level, we carried out a multivariable binary logistic regression model.

The univariate logistic regression model can be expressed as,

$$[\frac{\pi(X_i)}{1-\pi(X_i)}] = \beta_0 + \beta_1 X_i$$

where the quantity $\pi(X) = E(y_i|X)$ represents the conditional probability that Y=1 (stunted) given X and expressed as,

$$\pi(X_i) = \frac{e^{\beta_0+\beta_1 X_i}}{1+e^{\beta_0+\beta_1 X_i}};$$

If one considers a collection of p independent variables denoted by the vector X_i = (X1, X2, …, Xp) then the multivariable logistic regression model is given by the equation as

$$[\frac{\pi(X_i)}{1-\pi(X_i)}] = \beta_0 + \beta_1 X_{1_i} + \beta_2 X_{2i} + ----+ \beta_p X_{pi}$$

Before conducting the multilevel model, we calculated the intra-class correlation coefficient (ICC) by using the formula,

$$ICC = \frac{var(U_{0j})}{var(U_{0j}) + (\frac{\pi^2}{3})}$$

where $var(U_{0j})$ is the random intercept variance, i.e., the level-2 variance. The value of ICC ranges from 0 to 1. Only when the ICC is greater than 0 then a multilevel logistic regression model is applicable [22].

Finally, we performed a multilevel mixed-effects logistic regression model using the exact independent and dependent variable we used in the previous model. The equation of the multilevel model can be written as,

$$logit\ (\pi_{ij}) = \beta_0 + \beta_k X_{ij} + u_j$$

where i and j refer the level-1 and level 2 respectively and $u_j \sim N(0, \sigma 2)$.

To evaluate the strength of the association between "stunting" and determinant factors we used adjusted odds ratios (AORs) with 95% confidence intervals (CIs) and associations with p-value < 0.05 defined as a significant association for both models. As our main goal was to identify the best-fitted models we performed several goodness of fit tests e.g., Akaike information criterion (AIC), the Bayesian information criterion (BIC), and Log-likelihood. After comparing the AIC and BIC values for each model, the lowest one was deemed to be the better explanatory model (de Jong & Heller, 2008). The Area under the Receiver Operating Characteristic (AUROC) is also constructed which is the indicator of sensitivity and specificity. Lower P-values in the ROC curve indicate that the model can differentiate between two groups, and the area under the curve is greater than 0.50 [23].

Results

A total of 7902 child mothers participated and gave their information on 7881 children. Among them, 30.48% of children were stunted. It is evident that most of the stunted children (38.54%) were in poor family settings in Bangladesh. About 30% of these families have more than three family members and 46% of children with birth order 7-10 are most likely to suffer from stunting. In comparison to urban areas (25%), the prevalence of stunting in children under the age of five was higher in rural areas (32%). Geographic location (division)–wise distribution of prevalence presents that Sylhet was a high-risk area for stunting, where the prevalence was about 42%, and Dhaka and Khulna divisions were the low-risk areas for stunting.

However, the greatest number of stunted children was found in the families where household heads are involved in an agricultural occupation (40%). From the study we can see, fathers with no academic education have 43% stunting rate in their children and with primary education, the rate is 35.55%. Moreover, mothers with higher education have a huge contribution to reducing the prevalence of stunting to 15%. While we can see with no education 42% of mothers increase the possibility of stunting. But in some households, the prevalence of stunting is high (33%) because of working mothers. In Bangladesh, 32% of females in the age range 15-19 have children with stunting problems.

In general, the prevalence of stunting rises with the age of the child but mostly it is noticeable in the children (38%) who are between (24-35) months of age range. However, children whose mothers got antenatal care (more than 4 times) before delivery had a considerably decreased rate of stunting (25%) compared to those (33%) who didn't. At the same time mothers who didn't go through cesarean delivery (34%) increase the possibility of having stunting in their children. The stunting rate among children is high whose mother's place of delivery is home (35%) rather than the hospital (24%). We found that stunting prevalence is higher among children whose mothers had no access to those mass media. In Bangladesh, most of the households don't have improved toilet facilities (32%). In the two weeks leading up to the survey, about 30% percent of stunned children had diarrheal episodes, fever, and cough in particular (**Table 1**).

Both models, multivariable logistic regression and multilevel logistic regression refer to a degree of association between stunting status and socio-demographic profiles of children. In both analyses, there are significant variations that explain which model will be most preferable for this study. The odds ratio of division from the multilevel logistic regression model shows that Sylhet had 2 times (OR: 2.01, 95% CI: 1.47 - 2.75) greater chance of being stunted than Dhaka. It also gives a clear result about the Chattogram division (OR: 1.41, 95% CI: 1.00-1.98) which had a 41% higher chance of being stunted than Dhaka. According to the mother's education level, all categories such as no education, primary and secondary are significantly correlated with children stunting in both models. But the noticeable matter in the multilevel model is mothers with no education had 2.06 times (OR: 2.06, 95% CI: 1.41 - 3.02) higher chance of having stunted children than the women with higher education. Similarly in fathers with no education had 2.03 times (OR: 2.03, 95% CI: 1.51 – 2.72) higher chance of having stunted children than the father with higher education.

By comparing both models, it is evident that household heads with agricultural occupations had 29% (OR: 1.29, 95% CI: 1.00 - 1.66) higher chance in the multivariable model and 40% (OR: 1.40, 95% CI: 1.03 - 1.89) higher chance of stunting in a multilevel model of having stunting in their children. Though farmer's categories are significantly associated in the multivariable model but in the multilevel model it is not. So, it represents that farmers' categories are apparently not associated with stunting problems among children when we seek the genuine result. Moreover, in the multilevel model we see that poor family settings had 51% (OR: 1.51, 95% CI: 1.21-1.89) higher than rich families. Based on child age, when all other variables are adjusted, the most vulnerable age group (24-35) months children had 3.03 times (OR: 3.03, 95% CI: 2.42- 3.80) higher chance of stunting than 0-11 months children. However, all the children's age groups are significantly associated with stunting than the (0-11) months age group in the multilevel model. (**Table 2**).

In this analysis, the values of AIC, and BIC for multivariable and Multilevel models are 8997.297,9198.979 and 8985.347, 9193.984 respectively. The lower value of AIC, BIC, and Log-likelihood indicates a better fit model. From both models, we found that the Multilevel regression model has the lowest value of AIC, BIC, and Log-likelihood (8997.297,9198.979, -4469.649) than the Multivariable model. This also implies that the addition of the regional characteristics enhanced the multilevel model's capacity to explain differences in childhood stunting between regions. Our model fitting criteria the AUC of receiver operating characteristic curve (ROC) was identified to be 0.6793(Asymptotic p-value: <0.001 and 95% CI: 0.66 - 0.69) and 0.7117(Asymptotic p-value: <0.001and 95% CI: 0.69 - 0.72) for our final Multivariable and Multilevel models showed higher area under curve than 0.50. Basically, a receiver operating characteristic curve (ROC curve) is a graph that presents how well a classification model executes across all classification thresholds. Generally, an AUC of 0.5 indicates that there is no discrimination, and greater than this is considered acceptable or excellent. In our study, the value of AUC is greater in the Multilevel regression model which is 0.7117. So, without any doubt, the Multilevel model is the better-fitted model for this study **(Table 3)**.

Discussion

In this study, the prevalence of stunting of under five years old children was found to be 30.48% in Bangladesh. At the individual level, mother's education, father's education, household head occupation, wealth index, and age of the child were significantly associated with stunting. On the other hand, the only division was a significant factor at the regional level.

In the present study, child stunting was found to increase as the mother's education level decreased. Similar results were found in other studies of Bangladesh, some developing countries, and a Nigeria's study [3,24,25]. The reason behind this result could be that educated mothers are more concerned about child nutrition and it also shows us the importance of female education to reduce malnutrition. For the father's education level, the study found evidence of similar consequences to the mother's education level. A study of different regions of Ethiopia also shows father education level is inversely correlated with child stunting [19,26,27]. So, this study revealed that education is a vital factor to ensure proper childcare in the country.

Household head occupation also plays an important role in child stunting. The study noticed that children raised in households with agricultural backgrounds, who are farmers or do other agricultural-related work, were more vulnerable to stunted growth than children raised in households with business owners. Mothers with agricultural occupations were also found as a risk factor for child stunting in studies of India and China [28,29]. Fathers and mothers with agricultural occupations need to stay the whole day in the field as a reason they could not take care of their children as much as a businessperson can.

As a consequence of the household head occupation, this study also identified that household wealth is also associated with child stunting. Children from poor and middle-class households are more likely to be stunted than children from rich families. A similar insight was found in studies of different regions of Ethiopia, Nepal, India (West Bengal), Nigeria, Rwanda, Indonesia [5,7,13,14,24,30–33]. Hence, we can easily see that child stunting in poor families is a worldwide problem. They hardly even manage their three meals in a day. So, it is difficult for poor families to afford household food, sanitation, and health care, all of which are key contributors to child stunting.

This study revealed that children in 24-35 months age group are more at risk of child stunting though children of all age groups were found to be significantly associated with stunted growth. There could be many reasons behind this output. Most importantly at two years old infants start to eat other food properly than breast milk. At that time children need other nutritional food to grow up properly. This could be a reason that lack of healthy and nutritious food affects the regular growth of children. A similar age group was found vulnerable in studies of Ethiopia, Rwanda, Eswatini, and in a study of Bangladesh using BDHS 2014 data [15,32,34,35]. There are many other studies where different age groups found to be more vulnerable to child stunting.[24,26,27,29,37,36,38].

At the regional level, the study evident that division was a significantly associated factor with child stunting. Among 8 administrative divisions, Chattogram and Sylhet division was found to be significantly associated with child stunting in the multilevel logistic regression model. Sylhet situated in northeastern part of Bangladesh which is most flood affected area and Chattogram is a coastal area where frequent waterlogging happened. It could a reason for which malnutrition as well as child stunting is severe in this division. Furthermore, low literacy, poverty, and other factors could be reason behind this. Sylhet division found the most vulnerable division for child stunting in another study of Bangladesh.[3,34,39].

Study strengths and limitations

The main limitation of the study is the BDHS 2017-18 is a cross-sectional data. Longitudinal research would have conducted for the profiling of study participants across time. Furthermore, we are unable to incorporate a variety of possible risk factors such as meals per day, hygiene practices related data, mother’s pre-pregnancy data etc. Regardless of these constraints, methodologically it was a very strong study, there are very few studies using this type of modeling.

Conclusion

Child stunting remains a developing topic in Bangladesh, about 30% of children under five years old are still being stunted. This study reveals that educated parents are playing a vital role in reducing child malnutrition. So, policymakers should take proper steps to increase the literacy rate as much as possible which would help the country in the long run. This study also identified that 24-35 months aged children are in more danger than others. Government and non-government organizations should arrange some programs to provide nutrient-dense foods to 24-35 months aged children. Moreover, it is necessary to minimize disparities, there is a clear need to eliminate economic inequalities and, eventually, poverty among households. In addition, the government should pay special emphasis to improve the nutrition condition of under-five children in areas with a high prevalence of child stunting particularly in the Sylhet division.

Declarations

Acknowledgements: We are grateful to the DHS team for allowing us to conduct the analysis of this study using the BDHS 2017-18 data set.

Author Contributions:

Mowmi A.N., Noor S.T.A, Islam M.N and Uddin M.J. in conceptualized the study, designed the analytic approach, managed and performed the analysis, interpreted the results, and drafted the manuscript. Uddin M.J. and M.A.B. Chowdhury helped with the analysis, interpreted the results, drafted the manuscript, reviewed, edited, and updated the manuscript.

Funding: The authors did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Availability of data and material: Data are available on request from the DHS program website (https://dhsprogram.com/data/dataset/Bangladesh_Standard-DHS_2017.cfm)

Ethics approval and consent to participate: This study did not require ethics approval as we used secondary data which is publicly available. Details of ethics approval for DHS is available at:https://dhsprogram.com/Methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm

Consent for publication: Not applicable

Competing interests: There are no potential conflicts (financial, professional, or personal) to disclose by any of the authors.

References

1. World Health Organization. *The UNICEF/WHO/WB Joint Child Malnutrition Estimates (JME) group released new data for 2021*. *6 May 2021* (2021).

2. UNICEF, WHO & World Bank. Levels and trends in child malnutrition - UNICEF-WHO-WB joint child malnutrition estimates. *UNICEF, New York, USA* (2015).

3. Sarma, H. *et al.* Factors Influencing the Prevalence of Stunting Among Children Aged Below Five Years in Bangladesh. *Food and Nutrition Bulletin* **38**, 291–301 (2017).

4. UNICEF. Ethiopia El Nino Emergency. *Fast Facts* (2016).

5. Bogale, B., Gutema, B. T. & Chisha, Y. Prevalence of Stunting and Its Associated Factors among Children of 6-59 Months in Arba Minch Health and Demographic Surveillance Site (HDSS), Southern Ethiopia: A Community-Based Cross-Sectional Study. *Journal of Environmental and Public Health* **2020**, (2020).

6. Bank, A. D. *2020 Global Nutrition Report: Country Nutrition Profiles*. *The burden of malnutrition at a glance* (2021).

7. Pal, A., Pari, A. K., Sinha, A. & Dhara, P. C. Prevalence of undernutrition and associated factors: A cross-sectional study among rural adolescents in West Bengal, India. *International Journal of Pediatrics and Adolescent Medicine* **4**, 9–18 (2017).

8. UN. *World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352)*. *New York, United* (2014).

9. Pramod Singh, G. C., Nair, M., Grubesic, R. B. & Connell, F. A. Factors associated with underweight and stunting among children in rural terai of Eastern Nepal. *Asia-Pacific Journal of Public Health* **21**, 144–152 (2009).

10. Chopra, M. Risk factors for undernutrition of young children in a rural area of South Africa. *Public Health Nutrition* **6**, 645–652 (2003).

11. Ew, M., An, M. & Kenyatta, J. *Nutrition status and associated factors among children in public primary schools in Dagoretti, Nairobi, Kenya*. *African Health Sciences* vol. 13 (2013).

12. Frongillo, E. A., de Onis, M. & Hanson, K. M. P. *Community and International Nutrition Socioeconomic and Demographic Factors Are Associated with Worldwide Patterns of Stunting and Wasting of Children 1,2*. https://academic.oup.com/jn/article/127/12/2302/4728669.

13. Senbanjo, I. O., Oshikoya, K. A., Odusanya, O. O. & Njokanma, O. F. Prevalence of and Risk factors for Stunting among School Children and Adolescents in Abeokuta, Southwest Nigeria. *J HEALTH POPUL NUTR* **29**, 364–370 (2011).

14. Afework, E., Mengesha, S. & Wachamo, D. Stunting and Associated Factors among Under-Five-Age Children in West Guji Zone, Oromia, Ethiopia. *Journal of Nutrition and Metabolism* **2021**, (2021).

15. Berhanu, G., Mekonnen, S. & Sisay, M. Prevalence of stunting and associated factors among preschool children: A community based comparative cross sectional study in Ethiopia. *BMC Nutrition* **4**, (2018).

16. Asfaw, M., Wondaferash, M., Taha, M. & Dube, L. Prevalence of undernutrition and associated factors among children aged between six to fifty nine months in Bule Hora district, South Ethiopia. *BMC Public Health* **15**, (2015).

17. Gelman, A. *et al. Bayesian Data Analysis*. *Bayesian Data Analysis* (2013). doi:10.1201/b16018.

18. Ramli *et al.* Prevalence and risk factors for stunting and severe stunting among under-fives in North Maluku province of Indonesia. *BMC Pediatrics* **9**, 64 (2009).

19. Tariku, E. Z., Abebe, G. A., Melketsedik, Z. A. & Gutema, B. T. Prevalence and factors associated with stunting and thinness among school-age children in Arba Minch Health and Demographic Surveillance Site, Southern Ethiopia. *PLoS ONE* **13**, (2018).

20. Khan, Md. & Shaw, J. Multilevel Logistic Regression Analysis Applied to Binary Contraceptive Prevalence Data. *Journal of Data Science* **Vol.9**, (2011).

21. Elkasabi, M., Ren, R. & Pullum, T. W. *DHS METHODOLOGICAL REPORTS 27 MULTILEVEL MODELING USING DHS SURVEYS: A FRAMEWORK TO APPROXIMATE LEVEL-WEIGHTS*. (2020).

22. Merlo, J., Chaix, B., Yang, M., Lynch, J. & Råstam, L. A brief conceptual tutorial of multilevel analysis in social epidemiology: Linking the statistical concept of clustering to the idea of contextual phenomenon. *Journal of Epidemiology and Community Health* vol. 59 (2005).

23. Cook, J. A. & Rajbhandari, A. Heckroccurve: ROC curves for selected samples. *Stata Journal* **18**, (2018).

24. Adekanmbi, V. T., Kayode, G. A. & Uthman, O. A. Individual and contextual factors associated with childhood stunting in Nigeria: A multilevel analysis. *Maternal and Child Nutrition* **9**, 244–259 (2013).

25. Prendergast, A. J. & Humphrey, J. H. Paediatrics and International Child Health The stunting syndrome in developing countries The stunting syndrome in developing countries. *Taylor & Francis* **34**, (2014).

26. Beyene Teferi, M. Prevalence of Stunting and Associated Factors among Children Aged 06-59 Months In Southwest Ethiopia: A Cross-Sectional Study. *Journal of Nutritional Health & Food Science* **4**, 1–6 (2016).

27. Geberselassie, S. B., Abebe, S. M., Melsew, Y. A., Mutuku, S. M. & Wassie, M. M. Prevalence of stunting and its associated factors among children 6-59 months of age in Libo-Kemekem district, Northwest Ethiopia; A community based cross sectional study. *PLoS ONE* **13**, (2018).

28. Liu, J., Sun, J., Huang, J. & Huo, J. Prevalence of malnutrition and associated factors of stunting among 6–23-month-old infants in central rural China in 2019. *International Journal of Environmental Research and Public Health* **18**, (2021).

29. Sk, R., Banerjee, A. & Rana, M. J. Nutritional status and concomitant factors of stunting among pre-school children in Malda, India: A micro-level study using a multilevel approach. *BMC Public Health* **21**, (2021).

30. Menber, Y., Tsegaye, D., Woday, A., Cherie, H. & Kebede, S. Prevalence of Stunting and Associated Factors among School Age Children in Primary Schools of Haik Town, South Wollo Zone, North- Eastern Ethiopia, 2017. *Journal of Clinical & Cellular Immunology* **09**, (2018).

31. Mulyaningsih, T. *et al.* Beyond personal factors: Multilevel determinants of childhood stunting in Indonesia. *PLoS ONE* **16**, (2021).

32. Nshimyiryo, A. *et al.* Risk factors for stunting among children under five years: A cross-sectional population-based study in Rwanda using the 2015 Demographic and Health Survey. *BMC Public Health* **19**, (2019).

33. Smith, T. & Shively, G. Multilevel analysis of individual, household, and community factors influencing child growth in Nepal. *BMC Pediatrics* **19**, (2019).

34. Bhowmik, K. R. & Das, S. On selection of an appropriate logistic model to determine the risk factors of childhood stunting in Bangladesh. *Maternal and Child Nutrition* **15**, (2019).

35. Simelane, M. S., Chemhaka, G. B. & Zwane, E. A multilevel analysis of individual, household and community level factors on stunting among children aged 6–59 months in Eswatini: A secondary analysis of the Eswatini 2010 and 2014 Multiple Indicator Cluster Surveys. *PLoS ONE* vol. 15 (2020).

36. Beal, T. *et al.* Child stunting is associated with child, maternal, and environmental factors in Vietnam. *Maternal and Child Nutrition* **15**, (2019).

37. Fantay Gebru, K., Mekonnen Haileselassie, W., Haftom Temesgen, A., Oumer Seid, A. & Afework Mulugeta, B. Determinants of stunting among under-five children in Ethiopia: A multilevel mixed-effects analysis of 2016 Ethiopian demographic and health survey data. *BMC Pediatrics* vol. 19 (2019).

38. Mahmood, T., Abbas, F., Kumar, R. & Somrongthong, R. Why under five children are stunted in Pakistan? A multilevel analysis of Punjab Multiple indicator Cluster Survey (MICS-2014). *BMC Public Health* **20**, (2020).

39. Das, S., Baffour, B. & Richardson, A. Estimation of child undernutrition for spatiodemographic small domains in Bangladesh An application of multilevel Bayesian model Estimation of child undernutrition for spatio-demographic small domains in Bangladesh: An application of multilevel Bayesian model. (2022) doi:10.21203/rs.3.rs-1237384/v1.

Appendix

Table and figures

Table 1: Distribution of child stunting in individuals and regional levels

	Child Stunting	
Variables	**Not Stunted N (%)**	**Stunted N (%)**
Child Stunting	5479 (69.52)	2402 (30.48)
Mother Age		
15-19	696.9 (67.90)	329.5 (32.10)
20-24	1914 (70.05)	818.3 (29.95)
25+	2869 (69.59)	1254 (30.41)
Mothers' Education		
No education	325.3 (57.57)	239.7 (42.43)
Primary	1392 (61.57)	868.7 (38.43)
Secondary	2734 (71.10)	1111 (28.90)
Higher secondary or above	1028 (84.97)	181.8 (15.03)
Fathers' Education		
No education	657.6 (56.92)	497.7 (43.08)
Primary	1729 (64.45)	953.8 (35.55)
Secondary	1877 (73.13)	689.6 (26.87)
Higher secondary or above	1122 (84.05)	213 (15.95)
Fathers' Age		
>=24	293.3 (66.74)	146.1 (33.26)
25-29	1172 (68.12)	548.3 (31.88)
30-34	1412 (70.86)	580.7 (29.14)
35+	2520 (69.92)	1084 (30.08)
Mothers' Work Status		
No	3373 (71.85)	1322 (28.15)
Yes	2106	1080

	(66.11)	(33.89)
Household Heads' Occupation		
Jobless	38.97	17.06
	(69.55)	(30.45)
Farmer	544.6	300.40
	(64.45)	(35.55)
Agriculture	350.3	241
	(59.24)	(40.76)
Business	1218	416.80
	(74.50)	(25.50)
Others	3243	1381
	(70.15)	(29.86)
Religion		
Islam	5016	2215
	(69.37)	(30.63)
Others	463.3	186.4
	(71.31)	(28.69)
Wealth Index		
Poor	2046	1283
	(61.46)	(38.54)
Middle	1061	450.5
	(70.2)	(29.8)
Rich	2372	668.2
	(78.02)	(21.92)
No. of Household Members		
>=3	684	282.4
	(70.78)	(29.22)
3>	4795	2119
	(69.35)	(30.65)
Household Heads' Sex		
Male	4732	2091
	(69.36)	(30.64)
Female	747.2	310.8
	(70.63)	(29.37)
No. of Antenatal Care		
>=4	1633	834.5
	(66.18)	(33.82)
4>	1653	569.7
	(74.37)	(25.63)
Mass Media facility		
No	2969	1580
	(65.27)	(34.73)
Yes	2510	821.5
	(75.34)	(24.66)
Cesarean Section		
No	2132	1128
	(65.4)	(34.6)
Yes	1265	358.4
	(77.93)	(22.07)

Children's sex		
Male	2867 (69.55)	1255 (30.45)
Female	2612 (69.51)	1146 (30.49)
Toilet facility		
Modern	1539 (76.76)	466 (23.24)
Others	3940 (67.06)	1935 (32.94)
Partners Schooling type		
School	4503 (71.98)	1753 (28.02)
Madrasha	243.1 (68.88)	109.8 (31.12)
Children Age		
0-11	1375 (80.25)	338.3 (19.75)
12-23	1082 (66.14)	553.9 (33.86)
24-35	944 (61.36)	594.6 (38.64)
36-47	990.4 (67.06)	486.5 (32.94)
48-59	1088 (71.76)	428.3 (28.24)
Place of delivery		
Home	1580 (64.19)	881.6 (35.81)
Hospital facility	1821 (75.03)	606 (24.97)
Birth Order		
1-3	4899 (70.97)	2004 (29.03)
4-6	549.2 (59.7)	370.7 (40.3)
7-10	30.33 (53.13)	26.76 (46.87)
Fever		
No	3647 (69.89)	1571 (30.11)
Yes	1828 (68.81)	828.7 (31.19)
Cough		
No	3469 (69.39)	1530 (30.61)
Yes	2005	871.4

	(69.71)	(30.29)
Diarrhea		
No	5198 (69.32)	2300 (30.68)
Yes	277 (73.22)	10.3 (26.78)
Area of residence		
Urban	1560 (74.85)	524.2 (25.15)
Rural	3919 (67.61)	1877 (32.39)
Division		
Barisal	299.7 (67.37)	145.2 (32.63)
Chittagong	1108 (67.99)	521.5 (32.01)
Dhaka	1472 (74.74)	497.6 (25.26)
Khulna	550.7 (74.49)	188.6 (25.510)
Mymensingh	437.7 (65.34)	232.2 (34.66)
Rajshahi	632.1 (69.12)	282.3 (30.88)
Rangpur	598.4 (69.88)	258 (30.12)
Sylhet	380.7 (57.96)	276.2 (42.04)

Table 2: Factor associated with child stunting in multivariable and multilevel model

Covariates	**Multivariable Model**		**Multilevel Model**	
	OR (95% CI)	P-value	**OR (95% CI)**	P-value
Area of residence				
Urban	1		1	
Rural	1.006 (0.83-1.20)	0.947	1.05 (0.85- 1.29)	0.64
Division				
Dhaka	1			
Barisal	1.239 (0.94-1.62)	0.12	1.40 (0.99-1.96)	0.05
Chittagong	1.277 (0.98-1.65)	0.06	1.41 (1.00-1.98)	0.04
Khulna	0.947(0.71-1.25)	0.71	0.95 (0.66-1.35)	0.78
Mymensingh	1.24 (0.95-1.62)	0.10	1.38 (0.99-1.92)	0.05
Rajshahi	1.140(0.86-1.49)	0.34	1.15 (0.82-1.61)	0.41
Rangpur	1.00(0.76-1.31)	0.97	1.02 (0.73-1.43)	0.89
Sylhet	1.65(1.29-2.12)	<0.0011	2.01 (1.47-2.75)	<0.0011
Mothers' Education				
No education	2.00 (1.44-2.77)	<0.001001	2.06 (1.41-3.02)	<0.001001

Primary	1.87 (1.44-2.42)	<0.001001	1.99 (1.49-2.66)	<0.001001
Secondary	1.58 (1.26-1.98)	<0.001001	1.70 (1.32-2.20)	<0.001001
Higher secondary or above	1		1	
Fathers' Education				
No education	1.98 (1.52-2.59)	<0.001001	2.03 (1.51-2.72)	<0.001001
Primary	1.67 (1.33-2.11)	<0.001001	1.68 (1.37-2.17)	<0.001001
Secondary	1.39 (1.12-1.73)	0.003	1.41 (1.10-1.81)	0.006
Higher secondary or above	1		1	
Mothers' Work Status				
Yes	1		1	
No	1.06 (0.92- 1.23)	0.35	1.08 (0.92-1.26)	0.34
Household Heads' Occupation				
Business	1			
Jobless	1.30 (0.69-2.47)	0.40	1.26 (0.59-2.66)	0.53
Farmer	1.25 (1.01-1.56)	0.03	1.28 (0.99-1.64)	0.051
Agriculture	1.28 (1.00-1.65)	0.04	1.39 (1.02-1.89)	0.032
Others	1.14 (0.98- 1.33)	0.06	1.13 (0.95-1.34)	0.107
Wealth Index				
Poor	1.35 (1.11-1.64)	0.002	1.51 (1.20-1.89)	<0.001001
Middle	1.19 (0.99-1.43)	0.059	1.25 (1.00-1.56)	0.04
Rich	1			
Mass Media facility				
No	1.14 (0.99-1.31)	0.064	1.07 (0.91-1.26)	0.37
Yes	1			
Birth Order				
1-3	1		1	
4-6	1.15 (0.96-1.39)	0.11	1.16 (0.94-1.43)	0.15
7-10	1.17 (0.60-2.28)	0.63	1.10 (0.54-2.22)	0.78
Children Age				
0-11	1			
12-23	2.15 (1.78-2.61)	<0.001001	2.49 (2.01-3.08)	<0.001001
24-35	2.63 (2.16-3.19)	<0.001001	3.03 (2.42-3.80)	<0.001001
36-47	1.98 (1.63-2.39)	<0.001001	2.24 (1.80-2.79)	<0.001001
48-59	1.52 (1.25-1.84)	<0.001001	1.65 (1.34-2.04)	<0.001001

Table 3: Goodness of fit table

	Multivariable logistic regression Model	Multilevel mixed-effects logistic regression model
Area Under ROC Curve (95% CI)	0.6793(0.66660, 0.69209)	0.7117(0.69933, 0.72399)
AIC	8997.297	8985.347
BIC	9198.979	9193.984
Log-likelihood	-4469.649	-4462.674