Non-Linear Effects of Continuous Predictors on Malnutrition Status of Children in Bangladesh

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Abstract: *Background*: To explore non-linear effects of continuous covariates on response variable, generalized additive model (GAM) has now been extensively used. The main aim of this study is to explore the non-linear effect of some selected continuous covariates on malnutrition status of children in Bangladesh using logistic additive model.

Methods: To determine the factors of malnutrition status of children in Bangladesh, data are excluded from Bangladesh Demographic and Health survey 2014 (BDHS 2014). The anthropometric index of nutrition status, stunting is used as binary response variable and several demographic, socio-economic and health related variables are used as covariates. Bivariate analysis and additive logistic regression model is used to uncover the non-linear effect of included continuous variables as well as effect of categorical covariates on stunting in the study.

Results: The analysis exposes that mother's current age, mother's BMI and child's age have significant non-linear impact on stunting of children.

Conclusion: The analysis suggests that to improve nutrition status of children in Bangladesh, the government should take necessary steps targeting women in higher and lower age groups and women with higher and lower BMI. Moreover, the children after 20 months should be properly taken care of for achieving better nutritional health.

Keyword: Child's age, Generalized additive regression model, Malnutrition, Mother's age, Mother's BMI, Non-linear effect, Stunting.

INTRODUCTION

Nutritional status is one of the most important prerequisites for better health status and growth in national productivity. Now-a-days, malnutrition has become a major challenge in developing countries like Bangladesh in development of public health sector. According to WHO, malnutrition refers to deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients [1]. Malnutrition has negative effects on brain development causing delays in motor and cognitive development such as attention deficit disorder, impaired school performance, decreased IQ scores, memory deficiency, learning disabilities, reduced social skills, reduced language development, reduced problem-solving abilities [2]. Moreover, undernourishment has a strong association with respiratory disease and child mortality [3].

Poor nutritional status among children is one of the most important health and welfare problems in Bangladesh. According to Bangladesh Demographic and Health survey 2014 (BDHS 2014) report, 36% of children under age 5 are reported as stunted. Although the Health, Population, Nutrition Sector Development Program (HPNSDP) 2011-16 targets for 2016 for stunting [4] and Millennium Development Goal (MDG)

for eradicating poverty and hunger are achieved [5], still now the percentage of being stunted stands on the verge of the target. Moreover, Bangladesh is heading towards achieving Sustainable Development Goal (SDG) that targets to reduce stunting rate among under five children to zero percent by 2030 [6] and for that it is very urgently needed to identify the factors that affects the stunting rate in early life of a child. The problem of malnutrition both affects individuals and its effects are continued from one generation to the next as malnourished mothers give birth to under nutrient infants [7]. If these children are girls, a generation of malnourished mothers will thrive which will result in another malnourished generation. Thus country will face a generation cycle of malnutrition in future and it will become a burden on overall economic progress of country.

Many socio-economic, demographic and health related factors are found to be influential for the growth of this problem in several studies [8-17]. Das and Gulshan [8] used logistic regression model to examine the extent of malnutrition status among children in Bangladesh in a recent study. Talukder [16] assessed the covariates that influence malnutrition status of children through proportional odds model. Bhowmik and Das [17] applied linear regression, logistic regression and multiple classification analysis to rank the significant covariates that affect nutrition status of children. Takele [14] identified some factors that influence nutrition status of children in Ethiopia through

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Bayesian semi-parametric regression model. Srinivashan *et al*. [12] attempted to compare urban rural disparities in Bangladesh and Nepal through quantile regression model.

The main aim of this paper is to explore the non-linear effect of continuous covariates along with the adjusted effect of several categorical covariates on nutritional status of children in Bangladesh. For this purpose, Generalized Additive Model (GAM) has been used. It has become an elegant and practical option in model building to predict non-linear effect of continuous covariates on response variable by considering smoothing effect of the continuous covariates. For purpose of analysis, data from Bangladesh Demographic and Health Survey 2014 (BDHS 2014) have been used.

METHODS

Data and Variables

To analyze malnutrition status of children in Bangladesh, data are extracted from Bangladesh Demographic and Health Survey (BDHS), 2014. This survey was implemented under the authority of the National Institute of Population Research and Training (NIPORT), Ministry of Health and Family Welfare funded by USAID as a part of The DHS Program [4]. This survey was based on two-stage stratified sample of households. In first stage, enumeration area (EA) was selected with probability proportional to size. In second stage, a systemic sample of 30 households on an average per EA was selected. All ever-married women of age 15-49 who were usual member of household or who spent the night before the survey in the selected households were interviewed for the purpose of collecting information on various demographic, socio-economic and health related phenomena.

In this study, the main focus is to analyze the nutritional status of children in Bangladesh. There are three indices that explain the nutritional status of children. These are stunting, wasting and underweight. Among those, stunting reflects chronic malnutrition status of a child. Stunted growth is a primary indication of malnutrition and recurrent diseases in early childhood. If anyone is victim of stunting in childhood, its effect will be permanent for his whole life. That is why, the study considered stunting as response variable to assess the impact of demographic, socio-economic and health related variables on malnutrition status of children. A child who is more than two

standard deviations below the median (-2 SD) of the WHO reference population in terms of height-for-age is considered short for his or her age, or stunted [18]. It is considered as a binary response variable.

One of the aims of this study is to assess the non-linear effect of continuous predictors on malnutrition status of children. On the basis of literature, three continuous variables are included as independent variable: body mass index (BMI) of mother, current age of mother and age of child. Moreover, categorical covariates are also considered in this study to find the potential factors of malnutrition status based on literature review. These are: division (Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur, Sylhet), place of residence (Urban, Rural), mother's educational status (No Education, Primary, Secondary and Higher), wealth index (Poor, Middle, Rich), exposed to media (Yes, No), birth order (First birth, Others), antenatal care (Yes, No), place of delivery (Home, Hospital and others), mother's working status (Yes, No), awareness of child's health (Yes, No), NGO membership of mother (Yes, No), age difference between parents(<3, ≥3), violence to women (Yes, No), sex of child (Male, Female), disease status of child (Yes, No). All of these variables are not obtained directly from the survey data. The variable "exposed to media" was created based on the information of watching television, listening radio and reading magazine or newspaper. If mothers are associated with any one of the following Non-governmental Organizations (NGOs): Grameen Bank, Bangladesh Rural Advancement Committee (BRAC), Bangladesh Rural Development Board (BRDB), Association of Social Advancement (ASA), Proshika, Mother's club or others then they belong to 'Yes' category otherwise belong to "No" category. Violence to women is a proxy variable for a woman's perception towards her status. A score is created based on women's opinion on whether a husband is justified in hitting or beating his wife under a series of five circumstances. If any of the reasons is justified then it is assumed that the respondent is victim to domestic violence otherwise not. Age difference is nothing but the differences between current age of father and mother of a child, respectively.

In this study, children born preceding 3 years of BDHS 2014 survey have only been considered to study the recent pattern of malnutrition status of children in Bangladesh. In BDHS-2014 data, 4494 cases were available. But among them, we have many missing cases and /don't know" type answers. For instances,

we have 1 missing cases for antenatal care of mothers, 2 missing cases for place of delivery, 147 missing cases for child's age, 445 missing cases for stunting, 11 missing cases for exposed to media, 39 missing cases for BMI of mother, 134 missing cases disease status of child and so on. Again, two values of BMI of mother were found to be inconsistent compared to other values. These values were excluded at the stage of analysis. After excluding all those cases, 3934 observations were left for analysis. The variables which are found to be significantly associated with stunting status are only included as predictors in regression model.

Model Specification

Most of the recent research in statistical learning has concentrated on non-linear methods as for example polynomial regression models. Polynomial regression extends the linear model by adding extra predictor obtained by raising each of the original predictors to a power [19]. Generalized linear models (GLMs) attempt to approximate this unknown non-linear regression surface using polynomial function of predictors in systemic part as for example polynomial logistic regression [20]. But it has some serious problems like multicollinearity, subjectivity etc. Polynomial regression models become more complicated with large number of covariates. Prior knowledge about relation between response variable and predictors is necessary while applying polynomial regression but this may not be available in all cases [21]. A more sophisticated approach to predict such type of non-linear relationship is Generalized additive models (GAMs) proposed by Hastie and Tibshirani [22]. It has become an elegant and practical option in model building to predict non-linear effect of continuous covariates on response variable. The GAM extends the idea of GLM by considering the dependence between the response variable and covariates in a non-parametric fashion moving away from linearity assumption of GLM [23].

Let Y be response variable and $X = (X_1, X_2, \ldots, X_p)$ be set of continuous covariates. The generalized additive model can be written as

$$g(\mu) = f_0 + \sum_{j=1}^{p} f_j(X_j),$$

where μ is the expected value of response variable given covariates i.e., $E(Y|X) = \mu$. The functions $f_1, f_2, \ldots, f_p$ are unspecified smooth functions of continuous covariates $X_1, X_2, \ldots, X_p$, respectively and are modeled in a non-parametric way. The term `additive' is used because a more restrictive additive structure is used for assessing the effect of continuous covariates [22]. It calculates separate f_j for each X_j and then add them together all of their contributions. The term 'generalized' signifies that the response variable can be continuous, count or categorical. The same link functions $g(\cdot)$ that are used for GLM can be used in this model. As response variable considered in this study is binary in nature, logit link function $g(\mu) = \log\left(\frac{\mu}{1-\mu}\right)$ is considered in this study which is used for binomial probabilities [24]. These unspecified smooth functions $f_j's$ can be estimated by backfitting within local-scoring algorithm [25]. For analysis purposes, R package has been used [26].

RESULTS

To examine whether there is any relation between the response variable and continuous independent variables, analysis of variance has been used and results are presented using 95% error bars in Figure **1**.

It is clear from Figure **1** that for two groups, stunted and not stunted children, error bars are not overlapping each other for BMI of mother and age of index child. Though error bars are marginally overlapping for current age of mother, means of two groups are found to be significantly different with p-value equal to 0.023. Therefore, it can be concluded that there exists a significant relation between continuous variables and stunting of children.

To assess the measure of association between categorical covariates and response variable, chi-square test has been used. Table **1** presents the percentage distribution of stunting by several categorical demographic, socio-economic and health related characteristics. All covariates except age difference between husband and wife were found to have significant association with stunting of child. It is observed from the Table **1** that prevalence of stunting is highest in the Sylhet division (43.1%), whereas the lowest in Khulna division (28.9%). Children of rural area are more stunned compared to children of urban area (34.0% versus 29.8%). It is noticed that percentage of stunted children decreases with the increase in educational level of mother.

The proportion of stunted children is comparatively high among the poor (40.5%). It is found that 39.8% of
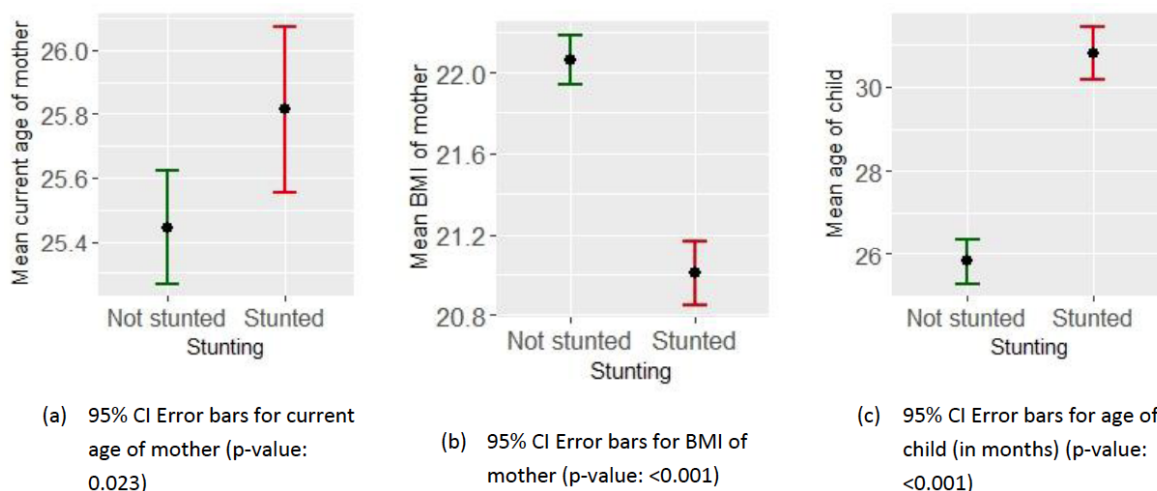
(a) 95% CI Error bars for current age of mother (p-value: 0.023)

(b) 95% CI Error bars for BMI of mother (p-value: <0.001)

(c) 95% CI Error bars for age of child (in months) (p-value: <0.001)

Figure 1: 95% CI Error bar for the mean of continuous variables included in the study by stunting for BDHS-2014 dataset.

Table 1:   Percentage Distribution of Stunting According to Different Demographic, Socio-Economic and Health Related Characteristics

Covariates (n)	% of not stunted	% of stunted	p-value
Division (4049)			<0.001
Barisal (486)	66.3	33.7	
Chittagong (768)	67.8	32.2	
Dhaka (716)	69.6	30.4	
Khulna (485)	71.1	28.9	
Rajshahi (498)	73.3	26.7	
Rangpur (511)	66.9	33.1	
Sylhet (585)	56.9	43.1	
Place of Residence (4049)			0.009
Rural (2746)	66.0	34.0	
Urban (1285)	70.2	29.8	
Mother's Educational Status (4049)			<0.001
No Education (543)	53.2	46.8	
Primary (1106)	60.7	39.3	
Secondary (1938)	71.1	28.9	
Higher (462)	84.2	15.8	
Wealth Index (4049)			<0.001
Poor (1608)	59.5	40.5	
Middle (797)	65.6	34.4	
Rich (1644)	75.8	24.2	
Exposed to Media (4039)			<0.001
Yes (2535)	71.6	28.4	
No (1504)	60.2	39.8	
Birth order (4049)			0.006
First Birth (1638)	69.8	30.2	
Others (2411)	65.7	34.3	

(Table 1). Continued.

Covariates (n)	% of not stunted	% of stunted	p-value
Antenatal Care (4044)			<0.001
Yes (3196)	70.9	29.1	
No (848)	53.9	46.1	
Place of Delivery (4034)			<0.001
Hospital and others (1623)	75.4	24.6	
Home (2425)	61.9	38.1	
Disease status of Child (4047)			0.001
Yes (1946)	64.7	35.3	
No (2101)	69.7	30.3	
Mother's Currently Working Status (4048)			0.002
Yes (880)	62.8	37.2	
No (3168)	68.6	31.4	
Awareness of Child's Health (4011)			0.004
Yes (2826)	69.0	31.0	
No (1185)	64.2	35.8	
NGO Membership of Mother (4049)			0.026
Yes (1210)	64.8	35.2	
No (2839)	68.4	31.6	
Age Difference (4004)			0.490
Less than 3 (544)	68.9	31.1	
More than or equal to 3 (3460)	67.3	32.7	
Violence to women (4005)			0.004
No (2902)	68.6	31.4	
Yes (1103)	63.7	36.3	
Child's Sex (4049)			<0.001
Male (2088)	64.4	35.6	
Female (1961)	70.4	29.6	

children are stunted whose mothers are unexposed to media. First child of mother is less stunned compared to other children of mother (30.2% versus 34.3%). Mothers who took antenatal care during their pregnancy period have less proportion of stunted child than mothers who did not take that care (29.1% versus 46.1%). The mothers who have delivered their child at home are more likely to have stunted children than the counterparts (38.1% versus 24.6%). Again, diseased child are more stunted (35.4%) than non-diseased (30.3%). Children of working women are more likely to be stunted (37.2%) than the children of unemployed mother (31.4%). On the other hand, women who are aware of their child's health are less likely to have stunted children (31.0% versus 35.8%). NGO

membership of mother and violence to women are playing a negative role on stunting of children. It is found that NGO members are more likely to have stunted children (35.2%) than the non-members (31.6%). Women who are victim to domestic violence are more likely to have stunted children than their counterpart (36.3% versus 31.4%). Male child are found to be at more risk of being stunned (35.6%) compared to the female child (29.6%).

Note that variables that were found to have statistically significant effect on stunting in bivariate analysis are only considered in the regression model GAM. The logistic GAM has been used to examine the non-linear effects of continuous covariates such as age and BMI of mother, age of child on the stunting of index

(a) Smoothing effect of mother's age(in years) with 95% confidence interval [V012=Mother's current age]

(b) Smoothing effect of mother BMI with 95% confidence interval [bmi_1=BMI of mother]

(c) Smoothing effect of child's age(in months) with 95% confidence interval [HW1.1=Child's age]
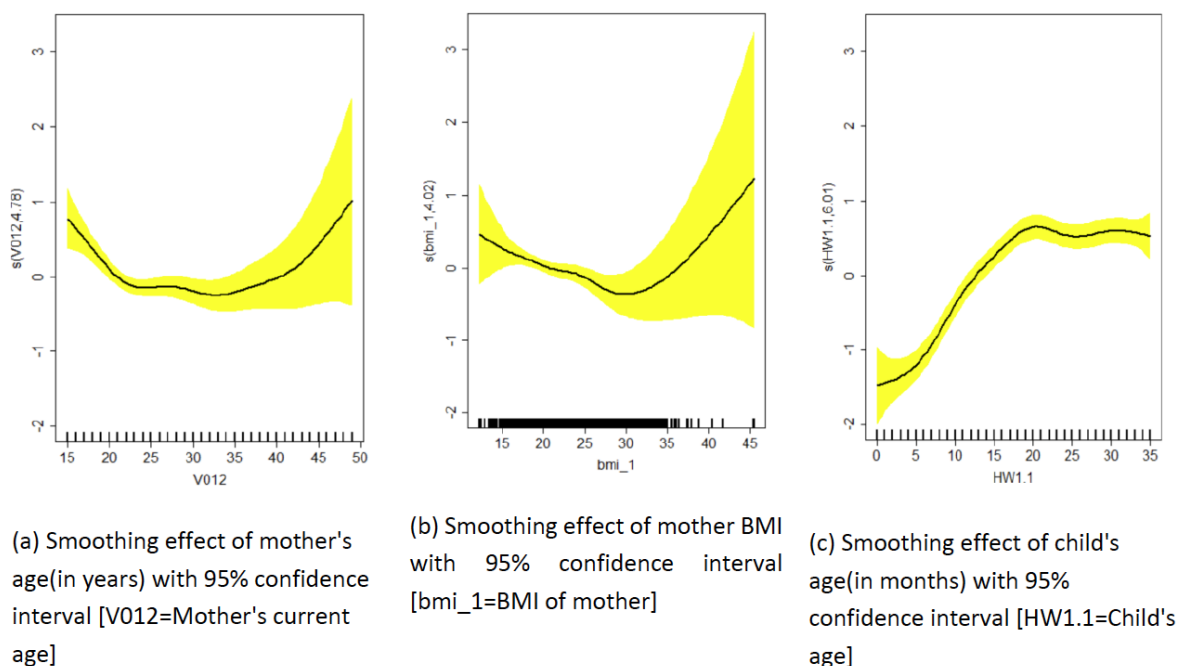
Figure 2: Estimated smoothing effects of continuous covariates included in the study on stunting with 95% confidence interval from BDHS-2014 data.

Table 2: Approximate Significance of Smooth Terms Obtained from the Additive Logistic Regression Model for Stunting from BDHS 2014 Data

Variables	Effective DF	p-value
Mother's age (in years)	4.775	<0.001
BMI of mother	4.015	0.021
Child's age (in months)	6.010	<0.001

child controlling other covariates. Figure **2** depicts the non-linear relationship between continuous covariates and stunting of children in Bangladesh and the effective degrees of freedom along with p-values are given in Table **2**.

It is clear from Table **2** that all continuous covariates have statistically significant non-linear effect on stunting as p-values are less than 0.05. Figure **2a** shows the adjusted smoothing effect of mother's age on stunting. It is observed that stunting is higher for children born to mothers less than 20 years and more than 40 years. At first the smoothing effect of mother's current age shows a decreasing pattern up to 20 years. From 20 years to 40 years of mother, the prevalence of being stunted is stable and in the children born to mother with current age greater than 40 years, the smoothing effect of stunting is high. Figure **2b** indicates the fact that there is a clear non-linear relationship between mother's BMI and stunting. At first there is a continuous decline in the prevalence of stunting till 30

kg/m^2. Then between 30 kg/m^2 to 35 kg/m^2 the prevalence of stunting comes down to the lowest point. After approximately 35 kg/m^2 of BMI of mother, the prevalence of stunting of child shows a sharp increasing upward trend. Figure **2c** represents the smoothing effect of age of child (in months) on stunting. It shows that in age group 0-20 months, the prevalence of stunting is increasing. Approximately at the age of 20 months, the curve is reaching to its highest point. After 20 months to 35 months, the stunting pattern stabilizes. The adjusted regression coefficients obtained from logistic GAM for qualitative covariates along with standard error, odds ratio, and p-value are given in Table **3**.

Division has significant adjusted effect on stunting. It is found that a child from other than Sylhet division has lower odds of being stunted. Place of residence has significant effect on stunting at 10% level of significance. The child belonging to urban area has 18.5% higher odds of being stunted than a child

Table 3:   Estimates of Regression Coefficients, S.E, Odds Ratio and p-Values Obtained from the Additive Logistic Model for Stunting from BDHS 2014 Data

Covariates	Coefficients	S.E	Odds Ratio	p-value
Intercept	0.149	0.165	1.161	0.365
Division				
Sylhet				
Barisal	-0.347	0.144	0.707	0.016
Chittagong	-0.325	0.128	0.723	0.011
Dhaka	-0.353	0.132	0.703	0.007
Khulna	-0.467	0.150	0.627	0.002
Rajshahi	-0.654	0.148	0.520	<0.001
Rangpur	-0.391	0.143	0.676	0.006
Place of Residence				
Rural				
Urban	0.170	0.090	1.185	0.059
Mother's Educational Status				
No Education				
Primary	-0.241	0.123	0.785	0.050
Secondary	-0.497	0.127	0.608	<0.001
Higher	-0.881	0.186	0.414	<0.001
Wealth Index				
Poor				
Middle	-0.048	0.107	0.953	0.650
Rich	-0.392	0.114	0.675	<0.001
Exposed to Media				
No				
Yes	-0.033	0.095	0.968	0.728
Birth Order				
Others				
First Birth	-0.251	0.111	0.778	0.024
Antenatal Care				
No				
Yes	-0.232	0.095	0.793	0.015
Place of Delivery				
Home				
Hospital and others	-0.183	0.088	0.833	0.038
Disease Status of Child				
No				
Yes	0.243	0.074	1.275	0.001
Mother's Currently Working Status				
No				
Yes	0.107	0.091	1.113	0.237

(Table 3). Continued.

Covariates	Coefficients	S.E	Odds Ratio	p-value
Awareness of Child's Health				
No				
Yes	-0.135	0.081	0.873	0.095
NGO Membership of mother				
No				
Yes	0.045	0.084	1.046	0.590
Violence to Women				
No				
Yes	0.005	0.083	1.005	0.950
Child's Sex				
Female				
Male	0.315	0.075	1.370	<0.001

belonging to rural area. It is observed that odds of being stunted for a child is decreasing significantly, as the level of education of mother is increasing. A child has 21.5% (p-value=0.050), 39.2% (p-value<0.001), and 58.6% (p-value<0.001) lower odds of being stunted if his/her mother has primary, secondary, and higher level of education, respectively compared to a mother with no education. A child from a rich family has 32.5% lower odds of being stunted than a child from poor family (p-value<0.001). The first child of parents is less likely to be stunted (22.2% lower with p-value=0.024) compared to a child with higher birth order. It is observed that the children whose mothers got better antenatal care are less likely to be stunted than their counterparts (p-value=0.015). A child born in hospital has 16.7% lower odds of being stunted than a child being born in home (p-value=0.038). Disease status of child is also significant at 5% level of significance (p-value=0.001). A diseased child has 27.5% higher odds of being stunted than a non-diseased. It is also revealed that awareness of child's health has significant adjusted effect on stunting of children at 10% level of significance and a child whose mother takes decision related to health has 12.7% lower odds of being stunted compared to a child whose mother is not aware of it. The result signifies that the male children are 37.0% more likely to be stunted than the female children (p-value<0.001).

DISCUSSION

Malnutrition of children is always considered as a hurdle for developing countries like Bangladesh. Though the nutrition status of children in Bangladesh has been improving because of enhanced attempts and interventions taken by government in past few decades, still there is a long way to go for achieving a well-nourished generation that will help in progress of overall national productivity.

This study has attempted to explore whether there is any non-linear effect of continuous covariates such as mother's current age, BMI of mother and child's age along with the adjusted effect of several categorical covariates on nutritional status of children in Bangladesh. The findings have clearly demonstrated that there exist non-linear relationships between the included continuous covariates and stunting of child. The findings of this study demonstrate that for mothers in lower and higher age group, the prevalence of stunting is relatively high. This may happen because younger mothers are less careful during the pregnancy and they have comparatively little knowledge about the proper growth of children. Moreover, prevalence of birth defects, premature labor, and low birth weight of infant are higher in lower and higher age group of mother. The mothers with lower and higher BMI are more likely to have stunted children which are similar to previous findings [8]. It may happen because good nutritional status of mother results in better nutritional condition of child and the mothers who suffer from malnutrition may not able to take care of their children in an effective way [8]. On other hand, from previous literature it is seen that the diet rich in calorie but poor in fruits and vegetables may encourage the mothers to be obese and children to be stunted at a time [27]. Such kind of imbalance in diet intake may cause the situation that high BMI of mother are more likely to have stunted children. Generally, majority of children

take external foods along with breast feeding after first 6 months. So, the effect of malnutrition due to food habit starts after a certain age. The finding of this study also supports this fact indicating that the odds of being stunted is relatively high in higher age groups of children [8].

Among categorical covariates, it is observed that Sylhet division has worst situation in case of malnutrition status of children that seeks more attention of policy-makers. Moreover, the result indicates that the children in urban areas are more vulnerable to stunting than children in rural area, which embraces previous findings indicating the declining urban-rural disparity [17]. It is also found that as the level of education of mother increases, the odds of being stunted for a child decreases which is also evident from previous researches [16]. It is very convincing that an educated mother must have a better knowledge regarding child's nutrition status and it helps her to provide a better diet for her child, which promotes a better health condition for child. The findings also highlighted that the stunting rate of child is also influenced by socio-economic indicator wealth index. The poorer the family is, the higher stunting rate among children is, that supports the findings of previous literature [8]. Food insecurity resulting from poverty may derive high stunting rate among children. Birth order also hold a significant relationship with stunting of child revealing that the first child of parents are less likely to be stunted possibly due to a mentality of paying more attention to first child than the others. The disease status of children significantly influences the nutritional status of them. Several diseases such as fever, cough or diarrhea may lead to malnutrition in tender stage of life [17]. The mothers who receive antenatal care during pregnancy and the mothers who have the chance to deliver their baby in hospital are less likely to have stunted children, which were also found in previous study [16]. It implies that if mothers are provided better care during pregnancy and accurate medical assistance, the stunting rate among children may reduce. Moreover, in several studies gender of child is found to have significant effect on malnutrition status [8] and this study explored that male child are more likely of being stunted than the female. It may happen because of awareness raising program about nutritional status among female child over the country and increasing concern for female child.

CONCLUSION

The findings of the study support that still there are a lot of demographic, socio-economic and health

related sphere where the policy-makers should concentrate. It is recommended from the findings that the higher and lower age groups of mother should be emphasized while interventions are implemented. Education about proper and balanced dietary intake for both mother and children should be provided among mothers. The children having age greater than 20 months should be taken care of as the probability of being malnourished is high among them. It can be strongly suggested from the findings of this study that Sylhet division should be prioritized while implementing project regarding nutritional status of children. Maternal education should be more wide spread. The public health approach must target poor families so that they can receive proper services regarding diet and knowledge preferable to better nutritional status of children. It is highly recommended that proper antenatal care and sufficient medical assistance during delivery of child should be strictly ensured for the betterment of child nutrition. Moreover, both male and female children should be treated equally to eradicate the curse of malnutrition from Bangladesh. Limitation of this study is that two-stage stratified sample has been used for the purpose data analysis, but the cluster effect has not been taken into account.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHORSHIP

TSS had the original idea of the study. TSS and WB conducted the statistical analysis and prepared the manuscript. Both authors read and approved the manuscript.

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