

The early marriage situation in Bangladesh: evidence from the MICS-2019 survey

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SUMMARY

The social issue of early marriage exists everywhere, including Bangladesh. The background elements connected to early marriage cases in Bangladesh are examined in this study. Early marriage is still very common, even though its incidence has been declining over time. To identify the factors that contribute to early marriage, a background analysis of respondents based on the MICS-2019 data was performed. A binary logistic regression was carried out to explore the factors that influence child marriage in Bangladesh. The model suggests that several factors, namely women's educational attainment, the family's wealth index, the age of the women studied, the household head's religion, and the household head's sex, were crucial in promoting early marriage. In addition to these characteristics, this study looked into whether exposure to ICT and household head ethnicity had any impact on early marriage. It was revealed by classification and regression tree analysis that there is a strong connection between these factors and early marriage, and the interactions of different factors like religion of household head, ICT exposure, etc., are found to be the combined causal factors of early marriage. Early marriage is a barrier to social progress. The progress of society as a whole will be aided by programs that encourage and assist girls to continue their education. To reduce child marriage, strict adherence to the legal minimum age for first marriage may be essential.

Key words: early marriage, multiple indicator cluster survey (MICS), socioeconomic factors, logistic regression

1. Introduction

Marriage is a legally recognized and sanctioned union of a man and a woman that is governed by laws, regulations, conventions, and religious beliefs. The

sexual union between a husband and wife is legalized by this union. One of the most significant demographic factors that helps us determine the social and economic aspects of any nation is marriage. However, early or child marriage is a social issue. Child marriage, according to UNICEF, is the union of a boy and a girl, or both, before they turn 18 (Lowe et al., 2019). Girls are more likely than boys to marry young, and this has a disproportionately negative impact on them, particularly in South Asian nations. According to this estimate, there are over 650 million early marriages worldwide, and even in the twenty-first century, 12 million child marriages occur each year. Therefore, it is unsurprising that early marriage occurs both in affluent nations as well as in developing and underdeveloped ones worldwide.

The majority of early weddings worldwide, roughly 45% of all marriages, occur in the South Asian region (UNICEF, 2014). Young marriage causes stress among girls (Nasrin and Rahman, 2012). The possibility of a promising future for women through obtaining a high degree and a suitable career is frequently eliminated by early marriage. In addition to this, it endangers the girls' health and is frequently associated with other physical issues. It is acknowledged as a social developmental impediment and a violation of human rights (ICRW, 2007). Women who get married young frequently become pregnant young, endangering the health of both the mother and the unborn child. In a nutshell, it has been established via previous studies and research that early marriage does harm in all spheres of life, including the family, society, and the country as a whole, due to its detrimental effects on the socioeconomic status of early married women.

Since we have mentioned that early marriage frequently causes early pregnancies in women, it follows that it also has an impact on population size. Teenage mothers have more children in their reproductive years than do their adult peers, and as a result, they are more likely to have a variety of health issues (Raj et al., 2009). The impact does not end at this point. According to a study, children of teenage mothers had twice the risk of dying as children of adult mothers, or women in their twenties (ICRW,

2007). In addition to all of these negative effects, early marriage seriously impairs the ability of women to make decisions for their families and, in the worst situations, exposes them to violence. This is sufficient to realize the detrimental effects of early marriage.

Although early marriage is a frequent practice throughout the world, it is especially prevalent in South Asia and parts of sub-Saharan Africa. There are undoubtedly a variety of elements that have an impact on its incidence in these areas. Poverty, ignorance, misconceptions about religious practices, and other issues are frequent. In addition to these, other factors are associated with this, and studies into these factors are frequently conducted to determine the causes, as the prevalence would be reduced if we could reduce the causes. By implementing diverse regulations and programs, national governments have chosen varied paths to reduce early marriage. To make this more successful, it is essential to identify the causes of early marriage and establish remedial measures in accordance with the desired outcomes.

In terms of population, Bangladesh ranks as the eighth-largest nation in the world. With a fertility rate of roughly 2.0 per woman, Bangladesh's population is on the rise. The child marriage situation in that country has improved over the past few decades. According to a report by UNICEF, 66% of Bangladeshi women get married before they turn 18, compared to roughly 59 percent in 2016 (UNICEF, 2011). Gender discrimination is a fairly common situation in Bangladesh, but it is declining with time. According to UNICEF's 2019 report, 25 percent of women give birth to children before turning 20. This statistic makes it evident how common early marriage is in the country. Islamic traditions and culture have a significant impact on the nation's culture as well. As is well known, a female is considered fit for marriage in Muslim culture if she can bear children. Many families misunderstand this idea and decide to marry off their daughters young. In addition, many families give their daughters early marriages to protect them from engaging in illicit relationships, which are prohibited by Islamic law

and are discouraged. In line with this idea, women in many Bangladeshi families are compelled to get married young to preserve the dignity of the family.

Bangladesh has a diversified economic structure. Because of this, families' financial situations vary greatly. The majority of families rely only on the father's income, and early marriage is also impacted by the economy. In urban slums, rural areas, and among poor families, early marriage is a highly prevalent occurrence. Early marriage rates are higher in some districts, including Sylhet, Chapainawabganj, Rangpur, Bhola, and some areas of the Khulna district (Gazi et al., 2013). The Child Marriage Act of 1929 expressly states that the minimum ages for marriage for boys and girls are 21 and 18 years, respectively; however, another study conducted by icddr,b found that approximately 64 percent of Bangladeshi women in the age range of 20 to 24 years had been married before reaching the legal age of marriage.

The issue is made clearer by comparison with other nations. Among the Asian nations, Bangladesh now has the highest rate of child marriage (about 52 percent). According to the global rankings for child marriage (marriage before the age of 15), this country is in fourth place, behind three African countries. Some of the aforementioned initiating variables, such as poverty and religious standards, have contributed to this vulnerability. Other than the fact that parents believe that getting their child married will guarantee their security, other reasons for early marriage include unequal access to school and employment opportunities, perceived lower values placed on girls in society, gendered norms, and harmful customs.

The people of Bangladesh are not highly concerned about the potential consequences of early marriage, and this unawareness is even more pronounced in rural areas. In Bangladeshi villages, the daughter's marriage is not discussed with her, and the girl frequently enters the marriage market as a result of manipulation or pressure from her family. The average age of marriage was 16.4 years, according to the Bangladesh Demographic and Health Survey (UNICEF, 2017). There are numerous government and

non-government groups aiming to increase public awareness and ensure major change in women's employment and education. The laws are currently strictly enforced to stop child marriage, and also the government is adopting many policies to enable women to reach equality and to decrease the rate of early marriage.

1.1. Background of the study

Early marriage is an alarming social issue, and many researchers in the fields of public health, demography, social science, and others have worked extensively in this area. To determine the causes and assist in putting plans in place to minimize them as much as possible, work is still being done. According to a study, women's education is the single most important component for combating early marriage (Kamal, 2012). The level of education for women and their partners, religion, wealth, and geography are some crucial characteristics that have a large impact on the occurrence of early marriage in Bangladesh, according to another study on the subject (Talukder et al., 2020). Other factors driving the practice include poverty, parents' reluctance to support their daughters' education, superstition, a lack of social security, and a lack of awareness. Even though child marriage is illegal, it nonetheless frequently occurs, especially in Bangladesh's remote districts, where there is inadequate enforcement and societal resistance (Kabir et al., 2019).

According to a research report (Raj et al., 2019), age heaping, also known as digital preference, is a complicating factor for child marriage in Bangladesh, when young girls falsely report their ages by saying that they are older or younger than they actually are. Education, age of the head of the household and their partner, and geographic region all revealed a significant correlation in all studies, even after age adjustment. In research, women's occupation has been identified as a significant outcome (Kamal et al., 2015), and a husband's occupation is also an important risk factor for early marriage (Shanjida et al., 2020; Rahman, 2017). Another thorough

survey that was conducted in numerous countries revealed that the number of family members, residence, wealth position, education levels of household heads and women, and mass media access were all major risk factors promoting early marriage (Ahmed et al., 2021).

In addition to these traditional criteria, there are several interesting factors that affect early marriage. According to a study, child marriage is apparently a coping mechanism used by households due to their greater susceptibility to natural disasters (Asadullah et al., 2021). Besides, the type of family – for example, joint family, nuclear family – is also among the determinants of child marriage (Rahman, 2017). The religion of the respondent has also been identified in multiple studies, and specifically, it is found that the practice is more prevalent among Muslims (Kamal et al., 2015; Hossain et al., 2016; Rahman, 2017).

By combining all of this research, we find that social security, education of the wife and her husband, financial situation, place of residence, and religion in the response demographics are the most commonly identified characteristics. Other important factors resulting in early marriage in Bangladesh include the usage of mass media, women's occupations, natural disaster risk, birth space, the type of family, and the number of people living in the household, among others.

1.2. Objectives of the study

The specific objectives of the study are to demonstrate the current situation of early marriage in Bangladesh using the MICS-2019 survey, by providing a descriptive overview of its prevalence. The study also aims to identify the key factors associated with early marriage through statistical analysis. In addition, it seeks to visualize the contributing factors and their interactions, and to draw meaningful inferences regarding their roles in shaping early marriage patterns.

2. Data and variables

The technique of data collection, as well as the background identification and dependent and independent variables of this study are discussed here.

2.1. Source of data

Data from the Multiple Indicator Cluster Survey (MICS) of Bangladesh for the year 2019 were used in this study. Since its creation by UNICEF in the 1990s, MICS has evolved into a nationally representative cross-sectional survey program that collects data based on various social and health indicators regularly to assess the socioeconomic and public health development of various countries around the world.

2.2. Sampling technique

The Bangladesh Bureau of Statistics (BBS) and United Nations International Children's Emergency Fund (UNICEF) jointly conducted the 2019 Multiple Indicator Cluster Survey (MICS). With a primary indicator that connects many development goals, MICS uses several household-related and women's questionnaires.

The two-stage stratified cluster sampling approach was used to acquire the data. There were 64,400 sample households and 3,220 primary sampling units (PSU) in total in the study, which covered all the districts of Bangladesh. The data were gathered using four distinct types of questionnaires, as follows:

1. A questionnaire about the household.
2. A questionnaire relating to water quality.
3. Two questionnaires for children under age 5 and for children aged 5–17 years.
4. A questionnaire for women.

Women between the ages of 15 and 49 were given the questionnaire. 68,709 individuals were included in the survey of the previously mentioned 64,400

households, making it a substantial sample. The data from the MICS were weighted, and the final sample size was 64,378 Bangladeshi women between the ages of 15 and 49. The detailed process is not explained here because the data used are secondary data. The Bangladesh MICS 2019 Report and the official MICS website both give more details of the structured system and layout for the data collection procedure.

2.3. Variables of the study

The data, combining all of the questionnaires, has more than eight hundred variables in total. In this section, we only mention the variables that are related to the purpose of the study. In the following subsection, we discuss the dependent and independent variables for our study.

2.3.1. Dependent variable

Age at marriage for women is the main variable of interest in this study. This variable was further divided into two categories: normal marriage and early marriage. Women are classified under ‘normal marriage’ if their age at the time of marriage was greater than or equal to 18 years, which is generally accepted as the minimum age for girls to get married. On the other hand, a marriage was referred to as an ‘early marriage’ if the age at which it took place was less than 18 years. The primary objective of the study is to examine the risk connected to this particular category of marital status using various pertinent independent variables, covered in the next subsection.

2.3.2. Explanatory variables

The study considers several independent variables based on their relevance to early marriage identified in previous literature. These include place of residence (urban or rural), women’s educational attainment, and household wealth index. These factors are widely recognized as important determinants of early marriage outcomes.

In addition, the education level of the household head is included as a proxy for household awareness and knowledge, which may influence early marriage practices. The religion of the household head is also considered, under the assumption that it reflects the religious affiliation of household members, and is included based on evidence suggesting cultural and religious influences on early marriage, particularly in Muslim-majority contexts.

The study further incorporates additional relevant variables identified in prior research. Among these, an indicator of exposure to ICT was constructed from multiple survey responses to capture access to communication technologies, which is increasingly relevant in the context of rapid technological expansion in Bangladesh. Age was categorized into three groups (15–24, 25–34, and 35–49 years) based on commonly used demographic classifications in similar studies (Saleheen et al., 2021). Finally, the sex and ethnicity of the household head are also included as potential influencing factors.

3. Methodology

This chapter discusses the specific method and tools used for the analysis of this study. The statistical theory and formulas that we used for the purposes of the research, and the statistical software used, are all described explicitly.

3.1. Chi-square test of independence

A commonly used method to assess the association between two categorical variables is the chi-square test of independence. This test evaluates whether there is a statistically significant relationship between variables based on a contingency table. The hypotheses for the test are defined as:

H_0 : The two variables are independent (no association exists).

H_1 : The two variables are not independent (an association exists).

The test statistic is given by:

$$\chi^2 = \sum_{i=1}^R \sum_{j=1}^C \frac{(o_{ij} - e_{ij})^2}{e_{ij}},$$

where o_{ij} and e_{ij} denote the observed and expected frequencies, respectively, and R and C represent the number of rows and columns in the contingency table. The statistic follows a chi-square distribution with $(R - 1)(C - 1)$ degrees of freedom. The null hypothesis is rejected if the calculated χ^2 value exceeds the critical value at a chosen significance level.

3.2. Binary logistic regression model

The output of the response variable in binary logistic regression is 1 (yes) or 0 (no), and it allows us to calculate the probabilities of a response depending on the covariates. For the study being done on early marriage, we defined two categories: early marriage and non-early marriage. While early marriage is the response of interest in this instance, we model it using binary logistic regression, as our response variable is a binary random variable. Relevant notations, equations, and descriptions are given below, for a better understanding of the method adopted in this study to model our response.

Let the outcome variable Y_i denote the response of the i^{th} observation. Now the response variable Y_i is categorized into

$$Y_i = \begin{cases} 1, & \text{if age at marriage is } < 18. \\ 0, & \text{if age at marriage is } \geq 18. \end{cases}$$

Let $X_{i1}, X_{i2}, \dots, X_{ip}$ denote the set of explanatory variables, which may be both quantitative variables or indicator variables presenting different categories of a variable. For the convenience of a given study, it might be necessary to convert continuous random variables into categories using statistical software, and this conversion often leads to a suitable outcome.

As mentioned earlier, the response variable is a Bernoulli random vari-

able, and so it is clear that this variable follows the Bernoulli distribution with parameter π_i . For the outcome, the probability of success is defined as:

$$P(Y_i = 1) = \pi_i = \frac{\exp(\beta_0 + \beta_1 x_{i1} + \dots + \beta_p x_{ip})}{1 + \exp(\beta_0 + \beta_1 x_{i1} + \dots + \beta_p x_{ip})},$$

where β_0 is the intercept and $\beta_1, \dots, \beta_p$ are the parameters of the linear regression model. The above equation can be re-expressed using the logit function for a simple expression, as follows:

$$g(X) = \text{logit}(\pi_i) = \log \frac{\pi_i}{1 - \pi_i} = \beta_0 + \beta_1 X_{i1} + \dots + \beta_p X_{ip},$$

where β_0 is the log odds and the other parameters $\beta_1, \beta_2, \dots, \beta_i$ quantify how the odds differ in the presence of the other variables. The next step is to estimate the parameters. For this purpose, we use the maximum likelihood technique. The likelihood is maximized by finding estimates of the parameters that are most likely to yield the data. The MLE (Maximum Likelihood Estimator) of β_0 and β_1 can be obtained by maximizing the following likelihood function:

$$L(\beta_0, \beta_1) = \prod_{i=1}^n \frac{\exp(Y_i(\beta_0 + \beta_1 X_i))}{1 + \exp(\beta_0 + \beta_1 X_i)}.$$

The estimation of the parameters can be performed using the MLE procedure, where we take the derivative of the log likelihood function with respect to a parameter and equate it to 0. Then, after a simple calculation, we find the estimate of the parameters.

The Wald test for the parameters and the Wald statistics-based confidence interval are used for testing the significance of the parameters. For the Wald test, let the estimated value of the parameter β be $\hat{\beta}$. Now the

Wald test statistic for testing the single parameter is given by

$$W = \frac{(\hat{\beta} - \beta)}{\hat{se}(\hat{\beta})}.$$

The above equation follows the standard normal distribution $N(0, 1)$. Squaring the above test statistic gives us the expression for the Wald test statistic as follows:

$$W^2 = \frac{(\hat{\beta} - \beta)^2}{\hat{Var}(\hat{\beta})}$$

which follows a χ^2 distribution with 1 degree of freedom. Hence, a value of the test statistic exceeding this value confirms the significance of the parameter estimated, $\hat{\beta}$. The Wald statistic-based confidence interval for a parameter β can also be generated using the following equation:

$$\hat{\beta} \pm z_{\frac{\alpha}{2}} * se(\hat{\beta})$$

which is the $100(1 - \alpha)\%$ confidence interval for the parameter β . From both the Wald test and the confidence interval, we can reach a conclusion about the significance of any parameter estimated from the model. The result for the estimated parameters in the binary logistic model is displayed as the odds ratio and the 95% confidence interval in the analysis part of this study. Besides, the p -values are mentioned as the significance level.

3.3. Odds ratio

The odds ratio (OR) is the measure of the relationship between the exposure variable and the outcome variable. OR measures the likelihood of an outcome under specific exposure conditions, as opposed to when that exposure is not present. Odds ratios are often employed in a variety of investigations, particularly epidemiological studies. The increase in log odds of the outcome for each unit increase in the exposure value is the regression coefficient in a

logistic regression. More specifically, the assessment of the odds ratio that is connected to a single unit exposure increase is an exponential function of the parameter. ORs are frequently used to determine how much the result of interest has been exposed to the variable of interest, also known as relative odds. This method, which has a straightforward interpretation that is simple enough for anyone to comprehend, is used to determine whether a specific exposure is to blame for a specific outcome.

Three possible interpretations of the odds ratio (OR) are as follows: $OR = 1$ indicates no association between exposure and outcome; $OR < 1$ indicates that the exposure is associated with a decreased likelihood of the outcome; and $OR > 1$ indicates that the exposure is associated with an increased likelihood of the outcome.

3.4. Classification tree technique

Machine learning techniques, such as classification trees and regression trees, are widely applied to identify nonlinear relationships in data and to examine interactions among predictor variables. The fundamental distinction between these approaches lies in the nature of the target variable: classification trees are designed for categorical outcomes, whereas regression trees are used for continuous outcomes. The Classification and Regression Tree (CART) algorithm is a machine learning method employed to predict target variable values based on a set of input features. The model constructs a tree-like structure in which each internal node represents a decision rule based on a predictor variable, while each terminal node (leaf) contains the predicted class label or numerical value of the target variable. CART employs the Chi-Square Automatic Interaction Detector (CHAID) technique. Since its creation, this has been widely applied in situations where predictive analysis is pertinent. CHAID is not restricted to binary scenarios, which means that it can connect a node or a single root with more branches than two.

As we have already established, the type of the variables employed as

answers determines how the classification and regression trees differ from one another. By utilizing a classification tree, the answer variable is divided into two categories, yes and no, which may be classified using the numbers 1 and 0. The classification tree then succinctly explains to us, using nodes, the most crucial elements that affect our results and how they interact with other relevant predictors or explanatory variables. In machine learning, the visualization is carried out using a code for a graph, providing us with a clear understanding of the relationships between the predictors and the outcomes.

3.5. Model performance and diagnostics

Model performance and diagnostic evaluation of the fitted logistic regression model were carried out using standard techniques for binary classification models. Receiver operating characteristic (ROC) curve analysis was used to assess the discriminative ability of the model. The ROC curve was constructed by plotting the true positive rate (sensitivity) against the false positive rate (1-specificity) across all possible classification thresholds. Sensitivity represents the proportion of correctly classified positive cases, while specificity represents the proportion of correctly classified negative cases.

The overall discriminatory ability of the model was evaluated using the area under the ROC curve (AUC). A higher AUC value indicates better model performance in distinguishing between the two outcome classes. The AUC was interpreted using commonly accepted guidelines, where a value of 0.5 indicates no discriminative ability, 0.7 to 0.8 indicates acceptable performance, 0.8 to 0.9 indicates excellent performance, and values above 0.9 indicate outstanding performance.

Model adequacy was further examined through residual diagnostics. Deviance residuals were plotted against fitted values to assess potential patterns, non-linearity, or lack of fit in the logistic regression model. Additionally, binned residual plots were used to summarize residual behavior across grouped fitted values, allowing clearer visualization of systematic deviations

from model assumptions.

In addition to residual-based diagnostics, multicollinearity among the independent variables was assessed using the Variance Inflation Factor (VIF). A VIF value greater than 10 was considered indicative of serious multicollinearity, while values below 5 were regarded as acceptable. All predictor variables exhibited VIF values within acceptable limits, indicating no evidence of harmful multicollinearity in the model.

3.6. Statistical software used

The majority of the analysis work, including cross-tabulation, test of association, and logistic regression, was completed using STATA software. SPSS was used to manage the data labels and to cross-check the findings from STATA, while R was used to cover the machine learning portion.

4. Analysis and results

In this chapter, we discuss at in detail the analysis of the prevalence of early marriage. As previously mentioned, early marriage is a social issue, and many factors are responsible for this social disease. The data used for the analysis are the MICS-2019 data. The study has a binary type of response variable, where the term 0 stands for a normal marriage of the respondent and 1 stands for an early marriage, which is our subject of interest.

4.1. Analysis of demographics

Bivariate analysis is the method employed in this study to determine whether a result has a significant correlation with several types of predictors. In short, we determine whether the presence of a variable has a significant impact on early marriage. We can observe from this study that the factors that have a significant impact on the response include the respondent's age, area of residence, education level for both women and the household head, wealth index, the sex of the household head, religion, ICT exposure, and

ethnicity. The following summary table is produced after this analysis is completed, one variable at a time.

Table 1. Analysis of early marriage based on different background characteristics.

Variables	Child marriage percentage	N	p-value
Age of women			
15–24	74.79	9034	
25–34	52.99	12294	<0.001
35–49	48.92	3046	
Area of residence			
Rural	61.89	19905	<0.001
Urban	54.85	4569	
Wealth Index			
Poorest	65.19	6073	
Poorer	66.46	5098	
Middle	62.84	4629	<0.001
Richer	58.3	4617	
Richest	46.3	4057	
Level of education			
None or pre-primary	58.83	2606	
Primary	67.54	5915	<0.001
Secondary	65.59	12219	
Higher secondary or above	34.39	3734	
Education level of HH head			
None or pre-Primary	62.79	7262	
Primary	65.14	7406	<0.001
Secondary	60.99	6877	
Higher secondary or above	42.61	2929	
Religion of HH head			
Muslim	61.95	21980	<0.001

Table 1 continued from previous page

Variables	Child marriage percentage	N	p-value
Non-Muslim	48.42	2494	
Exposure to ICT			
Exposed	53.58	16723	<0.001
Non-exposed	63.82	7751	
Sex of HH head			
Male	60.95	22646	<0.001
Female	55.96	1828	
Ethnicity of HH head			
Bengali	61.14	23896	<0.001
Others	37.2	578	

Table 1 shows that women between the ages of 15 and 24 have the highest rate of early marriage. Among this category of women, early marriage accounts for roughly 74.79% of all marriages. The prevalence for the age group from 25 to 34 is about 52.99%, which is a little lower than for the prior group. In this study, the age range of 35 to 49 has a prevalence of about 48.92% for cases of child marriage. Thus, early marriage is more common in younger age groups.

Early marriage is also related to the area of residence variable, which has two responses, urban and rural. The prevalence of child marriage is approximately 54.85% in urban areas and approximately 61.89% in rural areas. The rate is higher in Bangladesh's rural areas than in its cities.

Based on the *p*-value approach, the chi-square test of independence for respondent education level is statistically significant. In the category of women with no education or only a pre-primary level of schooling, the rate of child marriage is almost 58.83%. The rate rises in the following group, peaking at roughly 67.54% in the group with primary education. The rate then marginally declines in the group of women with secondary education, reach-

ing a value of roughly 65.59%, before substantially dropping in the group of women with higher secondary education, reaching a value of 34.39%. Thus, clearly the level of education of the respondent is highly responsible for the type of marriage: among more educated women there is a low rate of early marriage.

The religion of the head of the household is also a factor contributing to child marriage. There are two categories for this variable: Muslim and non-Muslim. The data reveal that the prevalence in the Muslim group is approximately 61.95%, while in the non-Muslim group it is lower, at 48.92%. Exposure to ICT is the next relevant variable, and it also shows a relationship with the subject of our research. With 63.82% of instances in the non-exposed group and 53.58% in the group of women who were exposed to ICT, the non-exposed group has significantly more cases than the other group.

The ethnicity variable, which is divided into two categories (Bengali and other) is the last important factor. The surprising finding is that whereas the prevalence of child marriage is roughly 37.2% among women of other ethnicities, it is approximately 61.14% among Bengali women. The latter group's rate is significantly higher than the former group's. We further analyzed the education level of the household head, which exhibited a dependency, and when examined in more detail, revealed findings similar to those for the variable education levels of women.

4.2. Logistic regression analysis

The binary response variable in this investigation required the use of logistic regression. The age at first marriage was employed as an outcome variable in this study, and the relevant variables related to it were taken from the preceding section.

Table 2. Results of unadjusted and adjusted logistic regression analysis of early marriage in Bangladesh

Characteristics	OR (Unadj.)	OR(Adj.)	95% CI	p-value
Age group				
15–24	3.12***	3.98	3.63-4.37	<0.001
25–34	1.17***	1.3	1.19-1.41	<0.001
35–49 (ref.)	1	1		
Area of residence				
Urban	0.75***	0.96	0.89-1.04	0.931
Rural (ref.)	1	1		
Education level				
None or pre-primary	2.72***	4.12	3.61-4.7	<0.001
Primary	3.97***	4.48	4.02-4.99	<0.001
Secondary	3.63***	3.66	3.34-4.07	<0.001
Higher secondary or above (ref.)	1	1		
Educ. level of HH head				
None or pre-primary	2.27**	0.85	0.76-0.95	0.007
Primary	2.51***	0.98	0.88-1.09	0.744
Secondary	2.1**	1.04	0.94-1.16	0.391
Higher secondary or above (ref.)	1	1		
Religion				
Non-Muslim	0.57***	0.64	0.58-0.71	<0.001
Muslim (ref.)	1	1		
Wealth index				
Poorest	2.17***	1.42	1.27-1.60	<0.001
Poorer	2.29***	1.41	1.26-1.57	<0.001
Middle	1.96***	1.34	1.21-1.49	<0.001
Richer	1.62***	1.24	1.12-1.37	<0.001
Richest (ref.)	1	1		
Exposure to ICT				

Table 2 continued from previous page

Characteristics	OR (Unadj.)	OR (Adj.)	95% CI	p-value
Exposed	0.65***	0.9	0.84-0.97	0.007
Non-exposed (ref.)	1	1		
Sex of HH head				
Female	0.81**	0.93	0.83-1.03	0.186
Male	1	1		
Ethnicity				
Non-Bengali	0.37***	0.44	0.36-0.54	<0.001
Bengali	1	1		

Note: *** indicates significant at 0.1%, ** indicates significant at 1% and * indicates significant at 5% level of significance.

Area of residence and sex of the household head both show non-significant odds ratios when we take all the variables into account to fit a model, as shown in the table of the binary logistic regression model. As a result, the primary conclusion we can draw about these variables is that they are not significant when we take all the other factors into account while fitting the binary logistic model. The other variables, however, are important in this study.

Women's ages as predictors were significantly correlated with child marriage. Thus, if we choose the age range of 35–49 as our reference group, the probability of getting married young for women in the first group is 3.98 times than that of the reference group (OR = 3.98, 95% CI 3.63–4.37), while the OR value for the second group is 1.3 (95% CI = 1.19–1.41), and both groups had significant odds ratios.

For level of education, the results were encouraging. Women with higher secondary education or higher made up the reference group, and relative to that group, the probability of an early marriage was 4.12 times more for women with no education (OR=4.12, 95% CI = 3.61–4.7), 4.48 times more for those with primary education (OR = 4.48, 95% CI = 4.02–4.99) and

3.66 times more for those with a secondary level ($OR = 3.66$, 95% $CI = 3.34-4.07$). This finding makes it very evident that women's educational attainment and likelihood of early marriage are significantly negatively correlated.

The household head's religion was also considered, being divided into two categories. This study indicated that non-Muslim women had 0.694 times the odds of being married before the legal age compared with Muslim women ($OR = 0.694$, 95% $CI = 0.626-0.77$), using Muslims as the reference group. It is clear from the results that Muslim girls in Bangladesh are more likely than non-Muslim girls to experience child marriage.

This study also discovered a strong association between the wealth index and early marriage. The probability of child marriage is 1.42 times higher in the poorest group ($OR = 1.42$, 95% $CI = 1.27-1.60$) than in the richest group, according to Table 4.2. The chances were 1.41 times higher for the poorer group ($OR = 1.41$, 95% $CI = 1.27-1.57$), 1.34 times higher for the middle group ($OR = 1.34$, 95% $CI = 1.21-1.49$), and 1.24 times higher for the wealthier group ($OR = 1.24$, 95% $CI = 1.12-1.37$) with respect to the richest group. The richest group was used as the reference group when calculating all odds. There is a strong negative correlation between a family's wealth and its support for child marriage.

The foundation of today's world is ICT. This study discovered a correlation between ICT exposure and the outcome of interest, given that ICT has made the globe more connected than ever before. In comparison to the non-exposed group used as the reference, it was discovered that the group of exposed women has a probability of early marriage 0.90 times that of the non-exposed group ($OR = 0.90$, 95% $CI = 0.84-0.97$). Hence, ICT exposure has a negative effect on Bangladeshi women's likelihood of early marriage, which is also significant.

Finally, there were two categories for ethnicity, and this study indicated that women who were not Bengali had a 0.445 times lower chance ($OR = 0.445$, 95% $CI = 0.361-0.54$) of being victims than those who were. The lo-

gistic regression table overall showed the exact amount of influence of each level or each factor on the outcome of interest, namely early marriage. The study used bivariate analysis to account for and find the exact significant factors and their levels responsible for the outcome.

4.3. Machine learning using classification tree

In this section, the classification tree is used to conduct additional analysis on the data. In addition to bivariate and binary logistic regression, this study also examined machine learning as a way to determine the most important variables and how they interact to determine the outcome. The

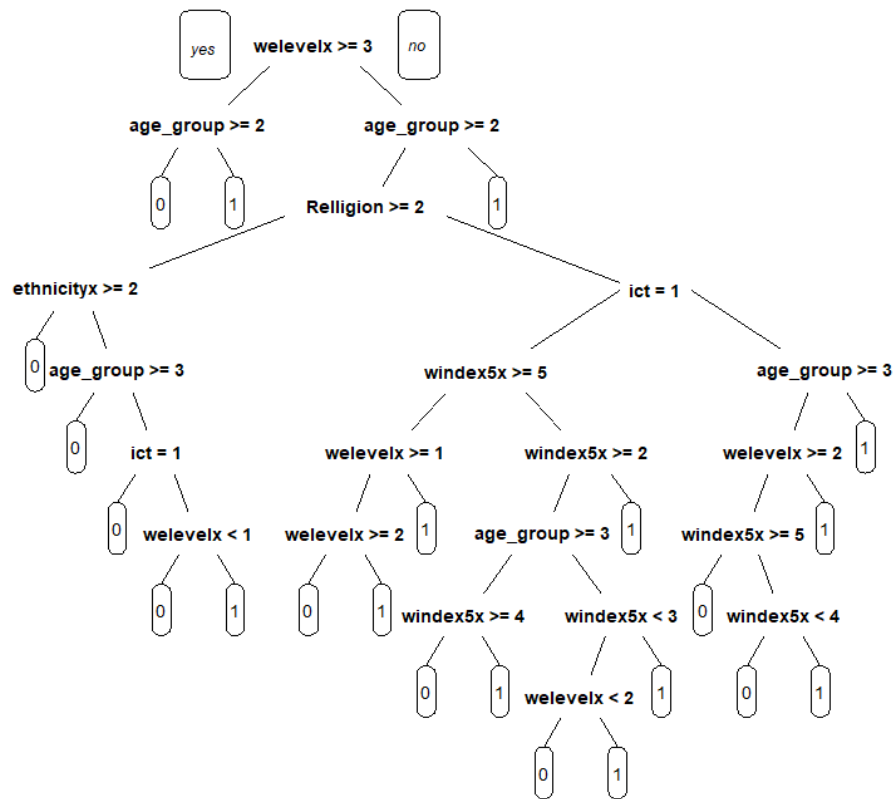


Figure 1. Classification tree of early marriage based on MICS-2019 data

classification tree for the dependent variable early marriage is presented in Figure 1. The outcome variable was dichotomized into early marriage and normal marriage, coded as 1 and 0, respectively. In the classification tree, *welevelx* denotes women's educational attainment, whereas *windex5* represents women's wealth index.

The classification tree analysis indicates that women with a higher secondary level of education or above are generally associated with a lower probability of early marriage and a higher likelihood of normal marriage. The interaction between educational attainment and age further demonstrates that women aged 35–49 years with higher secondary or higher education predominantly experience normal marriage patterns, whereas younger women with comparable educational levels exhibit a greater probability of early marriage.

Conversely, among women with educational attainment below the higher secondary level, early marriage appears to be more prevalent, particularly in older age categories. The results identify women's education as the most influential predictor in the classification model. Specifically, women with at least a higher secondary education are more likely to experience normal marriage outcomes when aged over 25 years, whereas early marriage remains more common among younger women. For women with no formal education up to a secondary level of education, marriage outcomes are further conditioned by age. Women older than 25 years are predominantly classified into the normal marriage category, while for younger women, religion emerges as an additional determinant.

Among non-Muslim women, ethnicity constitutes a subsequent discriminating factor. Non-Bengali women are more frequently classified into the normal marriage category. In contrast, among Bengali women, marriage classification is further influenced by exposure to information and communication technology (ICT). Women exposed to ICT are more likely to experience normal marriage, whereas among those without ICT exposure, educational attainment becomes an important determinant. Women with no

education or pre-primary education tend to exhibit normal marriage patterns, whereas women with higher educational levels within this subgroup demonstrate an increased likelihood of early marriage.

For Muslim women, ICT exposure emerges as an important predictive factor. Among women exposed to ICT, those belonging to the highest wealth category and possessing at least primary education are less likely to experience early marriage. In contrast, women with educational attainment below the primary level demonstrate an elevated probability of early marriage.

Among women without ICT exposure, age interacts with other predictors in determining marriage classification. Women younger than 35 years exhibit a higher prevalence of early marriage, whereas among older women, educational attainment becomes increasingly influential. Women with educational levels below secondary education remain at greater risk of early marriage. For women with secondary or higher education, wealth status further contributes to classification outcomes. Membership in the highest wealth category is generally associated with a greater likelihood of normal marriage after controlling for previously identified factors.

Among women without ICT exposure, age group emerges as an interacting factor in the classification process. Women younger than 35 years exhibit a higher prevalence of early marriage, whereas for women aged 35 years and above, educational attainment becomes a key determinant of marriage classification. Women with educational attainment below the secondary level demonstrate a greater likelihood of early marriage. Among women with at least a secondary level of education, classification outcomes are further influenced by additional socioeconomic characteristics, particularly household wealth status.

For women with higher educational attainment, the wealth index becomes an important discriminating factor. Women belonging to the highest wealth category are more likely to experience normal marriage outcomes after controlling for the previously identified factors. In contrast, among women outside the highest wealth category, wealth status continues to con-

tribute to the classification process and influences the probability of early versus normal marriage.

Similarly, other terminal nodes of the classification tree reveal interactions among demographic and socioeconomic variables that contribute to determining marriage outcomes. These interactions provide insight into the combined effects of multiple predictors on the likelihood of early marriage. Overall, the classification tree effectively visualizes the relative importance and hierarchical interactions of factors associated with marriage timing and resulting marriage categories.

5. Model diagnostics

5.1. Residual analysis

The traditional way of assessing the goodness of fit for a model is plotting the residuals. The following is the plot of residual vs, fitted value for the logistic regression model used in this study.

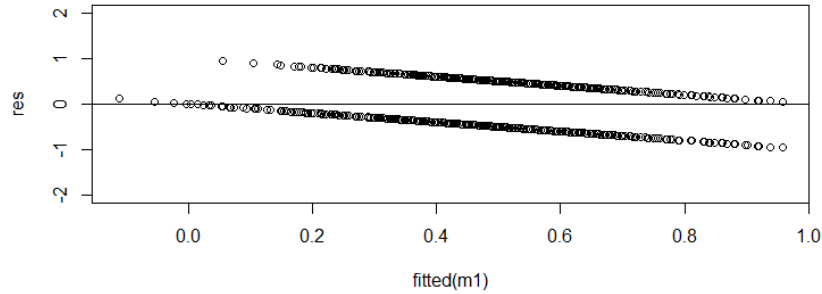


Figure 2. Plot of residual vs. fitted values for logistic regression

It should be noted that all of the points are near zero and range from -1 to 1 (Figure 2). Hence, the model appears to be suitable, but this graphic still does not provide us with a clear understanding of the fitted model. We use the binned residual (Figure 3) to resolve this issue. The following is a

plot of the binned residual against the predicted value:

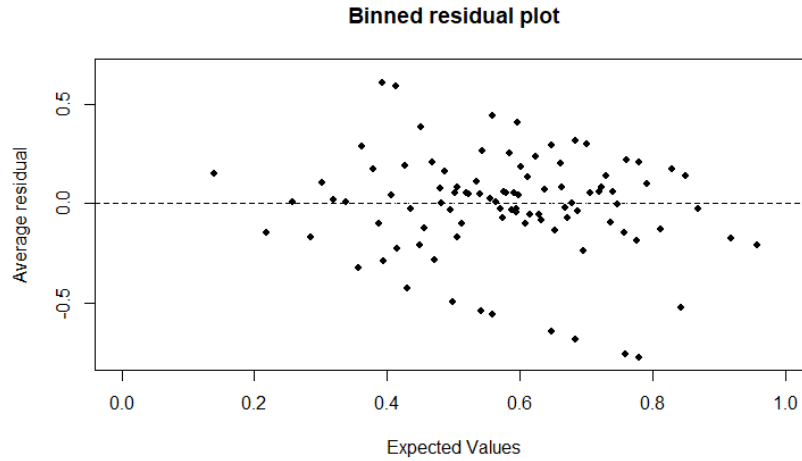


Figure 3. Plot of binned residuals for the logistic regression model

This plot shows that the residuals vs. the expected values lie on both sides of the line 0, and they are very close and without any pattern. This plot confirms that the logistic regression model we used in the study was appropriate and will yield expected results (Figure 3).

5.2. Prediction performance

The area under the ROC curve (AUC), which ranges from 0 to 1, provides a measure of the model's ability to discriminate between cases of early marriage and cases of normal marriage.

In Figure 4, the area under the ROC curve is 0.7354. This means that there is a 73.54% chance that the model will be able to distinguish between the cases of early marriage and normal marriage in Bangladesh.

Besides the multicollinearity assumption, VIF was checked and found to be below the value 2.5, which indicates that this study is not subject to any multicollinearity problem in fitting the model, and this confirms that the model we considered is appropriate.

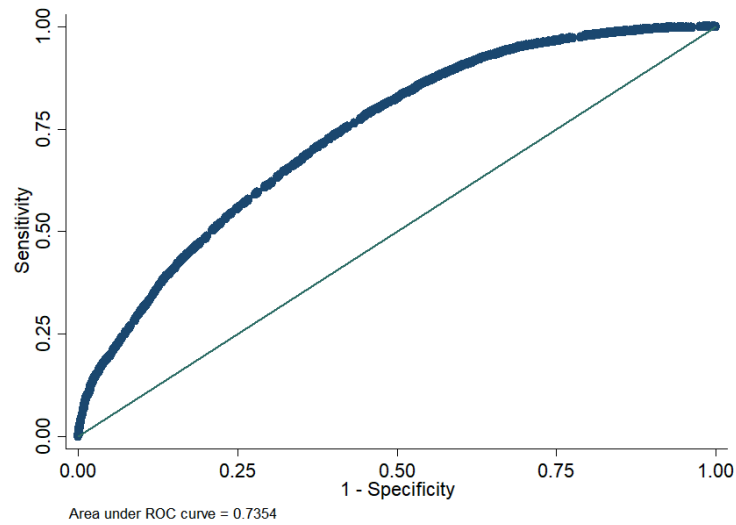


Figure 4. ROC curve for all possible cut points of sensitivity versus 1-specificity

5.3. Discussion and conclusion

Using MICS data for Bangladesh for the year 2019, this study aims to identify the key variables that influence early marriage. The study initially looked for a correlation between early marriage and the age of women, and discovered that older women are less likely than younger ones to have been married young. Several research studies have reached the same conclusions. The findings showed a connection between age and a propensity for early marriage. A previous study discovered that the location of one's dwelling is a factor influencing early marriage. However, the present study did not find it to be a significant factor for early marriage, although earlier studies have highlighted the conservative nature of rural areas (Saleheen et al., 2021).

The education levels of the women and household heads were investigated, and we found that the education level of women is a significant factor for early marriage. Girls with less education have a high rate of child marriage. Previous research also supports this finding and identifies women's education as a key determinant of early marriage (Saleheen et al., 2021;

Billah et al., 2023). Women with higher education are less likely to marry at a young age. This happens because higher education increases awareness of health risks and the appropriate marriage age, contributing to women's empowerment. Furthermore, recent evidence also suggests that early marriage negatively affects women's educational attainment and employment outcomes (Khan et al., 2024).

The study was unable to identify a connection between early marriage and household head education level. Intriguingly, our study revealed that households with lower levels of education were more concerned about early marriage among young people. Earlier research also indicated that households headed by less educated individuals tend to be more conservative regarding early marriage practices (Saleheen et al., 2021).

A girl who identifies as Muslim had a higher chance of getting married young, which is consistent with other research. The study also revealed that Muslim families were significantly affected by early marriage. Previous studies demonstrated that cultural and religious norms continue to influence early marriage practices across countries (Saleheen et al., 2021). Some families believe that getting married young is appropriate and that getting married later is undesirable, a notion particularly prevalent in rural settings.

This study also discovered that early marriage has a marginally significant relationship with ICT exposure. Women who have access to ICT are less likely to get married early, indicating a negative relationship. Increased access to information may improve awareness and decision-making. In Bangladesh, especially in rural regions, many families rely on a single source of income, and economic pressure may encourage early marriage.

The wealth index was also found to be significantly associated with early marriage. Families in the poorest, poorer, middle, and richer categories are more exposed to early marriage compared with the richest group. Previous studies reported similar findings, showing that economically disadvantaged households are more likely to marry off daughters early (Billah

et al., 2023). It has also been observed that early marriage rates are lower in settings where women have greater employment opportunities (Khan et al., 2024). There was no discernible effect of the household head's sex; although patriarchal families showed a higher incidence than matriarchal ones, the effect was not statistically significant. Finally, in terms of ethnicity, Bengali households practice early marriage more frequently than other ethnic groups, which is highly significant.

Although this study provides useful insights, several limitations should be acknowledged. First, the analysis is based on data from 2019, and changes in socio-economic conditions over time may affect the current relevance of the estimates. Second, the cross-sectional nature of the data limits the ability to make causal interpretations of the observed associations. Future research may build on this work by using more recent or longitudinal data, which would allow a better assessment of temporal changes and causal relationships. In addition, alternative modeling approaches that account for hierarchical data structures or heterogeneity across population subgroups could be considered where appropriate.

Finally, the findings highlight several socioeconomic factors influencing early marriage. The government of Bangladesh has undertaken initiatives such as Digital Bangladesh and Vision 2041 to improve education and connectivity. These efforts may help reduce early marriage. Ensuring access to quality education and expanding employment opportunities for women are crucial. Strengthening the enforcement of laws against early marriage is also essential. Increasing female education, employment, and legal enforcement remains critical for addressing this persistent social issue.

6. Declaration

Md. Azizul Kahar and Khondoker Shahriar Islam contributed equally to this work and are considered joint first authors. Khondoker Shahriar Islam is the corresponding author. Md. Azizul Kahar conceptualized the study and provided the research idea. Both authors wrote the main manuscript,

prepared the figures, and performed the data analysis. Khondoker Shahriar Islam contributed to the study design, data analysis, and interpretation, and provided critical feedback on the manuscript. Both authors reviewed and approved the final manuscript.

Rather than collecting primary data, the authors utilized secondary data from the 2019 Multiple Indicator Cluster Survey (MICS), conducted by the Bangladesh Bureau of Statistics (BBS) with technical assistance from UNICEF and UNFPA. Each respondent provided oral consent prior to the interview, and their identities were kept confidential. The dataset is nationally representative and can be accessed upon request from the Bangladesh Bureau of Statistics (BBS) website at <https://bbs.gov.bd/>. The authors declare no competing interests. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. We acknowledge the Bangladesh Bureau of Statistics (BBS), UNICEF Bangladesh, and UNFPA Bangladesh for providing access to the MICS dataset.

REFERENCES

- Adebowale S.A., Fagbamigbe F.A., Okareh T.O., Lawal G.O. (2012): Survival analysis of timing of first marriage among women of reproductive age in Nigeria: regional differences. *African Journal of Reproductive Health*, 16(4): 95–107.
- Asadullah M., Islam K., Wahhaj Z. (2021): Child marriage, climate vulnerability and natural disasters in coastal Bangladesh. *Journal of Biosocial Science*, 53(6): 948–967.
- Bezie M., Addisu D. (2019): Determinants of early marriage among married women in Injibara town, north west Ethiopia: community-based cross-sectional study. *BMC Women's Health*, 19(1).
- Billah M.A., Khan M.M.A., Hanifi S.M.A., Islam M.M., Khan M.N. (2023): Spatial pattern and influential factors for early marriage: evidence from Bangladesh Demographic Health Survey 2017–18 data. *BMC Women's Health*, 23(1): 320.
- Biswas R.K., Khan J.R., Kabir E. (2019): Trend of child marriage in Bangladesh: A reflection on significant socioeconomic factors. *Children and Youth Services Review*, 104, p.104382.

- Chowdhury S., Rahman M.M., Zayed N.M. (2020): Factors affecting early marriage in Bangladesh: an analysis on BDHS 2014 data. *International Journal of Humanities, Arts and Social Science*, 4(1): 40–47.
- Hossain M., Mahumud R., Saw A. (2016): Prevalence of child marriage among Bangladeshi women and trend of change over time. *Journal of Biosocial Science*, 48(4): 530–538.
- ICRW (2007): New insights on preventing child marriage: a global analysis of factors and programs. International Center for Research on Women, Washington DC.
- Islam M.M., Islam Md.K., Hasan M.S., Hossain M.B. (2017): Adolescent motherhood in Bangladesh: trends and determinants. *PLOS ONE*, 12(11): e0188294.
- Kabir S., Ghosh S., Shawly A. (2019): Causes of early marriage and its effect on the reproductive health of young mothers in Bangladesh. *American Journal of Applied Sciences* 16(9): 289–297.
- Kamal S.M. (2012): Decline in child marriage and changes in its effect on reproductive outcomes in Bangladesh. *Journal of Health, Population and Nutrition*, 30(3): 317–330.
- Kamal S., Hasan C., Alam G., Ying Y. (2015): Child marriage in Bangladesh: trends and determinants. *Journal of Biosocial Science*, 47(1): 120–139.
- Khan M.N., Khanam S.J., Khan M.M.A., Billah M.A., Akter S. (2024): Exploring the impact of perceived early marriage on women's education and employment in Bangladesh through a mixed-methods study. *Scientific Reports*, 14(1): 21683.
- Lowe M., Joof M., Rojas B.M. (2019): Social and cultural factors perpetuating early marriage in rural Gambia: an exploratory mixed methods study. *F1000Research*, 8, p.1949.
- Mim S.A. (2017): Effects of child marriage on girls' education and empowerment. *Journal of Education and Learning*, 11(1): 9.
- Montazeri S., Gharacheh M., Mohammadi N., Alaghband Rad J., Eftekhari Ardabili H. (2016): Determinants of early marriage from married girls' perspectives in Iranian setting: a qualitative study. *Journal of Environmental and Public Health*, 2016(1), p.8615929.
- Nasrin S.O., Rahman K.M. (2012): Factors affecting early marriage and early conception of women: a case of slum areas in Rajshahi City, Bangladesh. *International Journal of Sociology and Anthropology*, 4: 54–62.
- Palamuleni M.E. (2011): Socioeconomic determinants of age at marriage in Malawi. *International Journal of Sociology and Anthropology*, 3(7): 224–235.

- Porter E. (2013): Rethinking women's empowerment. *Journal of Peacebuilding & Development*, 8(1): 1–14.
- Raj A., Saggurti N., Balaiah D., Silverman J.G. (2009): Prevalence of child marriage and its effect on fertility and fertility-control outcomes of young women in India: a cross-sectional observational study. *The Lancet*, 373: 1883–1889.
- Rahman M. (2017): Determinants of early marriage in Bangladesh: evidence from a nationally representative survey. *International Journal of Sociology and Anthropology*, 9(1): 1–7.
- Saleheen A.A.S., Afrin S., Kabir S., Habib M.J., Zinnia M.A., Hossain M.I., Haq I., Talukder A. (2021): Sociodemographic factors and early marriage among women in Bangladesh, Ghana and Iraq: an illustration from Multiple Indicator Cluster Survey. *Heliyon*, 7(5): e07111.
- Talukder A., Hasan M.M., Razu S.R., Hossain Z. (2020): Early marriage in Bangladesh: a cross-sectional study exploring the associated factors. *Journal of International Women's Studies*, 21(1): Article 6.
- UNICEF (2005): Early marriage: a harmful traditional practice; a statistical exploration. United Nations Children's Fund, New York.
- UNICEF (2014): Child protection from violence, exploitation and abuse. United Nations Children's Fund.
- UNICEF (2019): Child marriage around the world. United Nations Children's Fund.
- UNICEF (2013): Child marriage in Bangladesh: findings from a national survey 2013. icddr,b and Plan International.