**Cesarean delivery and early childhood diseases in Bangladesh: An analysis of Demographic and Health Survey (DHS) and Multiple Indicator Cluster Survey (MICS)**

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**Abstract**

Background: The rate of cesarean delivery (C-section) has been increasing worldwide, including Bangladesh. As the C-section is a major surgery, it has a negative impact on the mother and child's health. In Bangladesh, not enough research is done to examine the increased risk of childhood diseases due to C-sections. Our aim was to examine the association between C-section and childhood diseases.

Methods: We used the latest available nationally representative data from a multiple indicator cluster survey (MICS, 2012 and 2019) and Bangladesh Demographic and Health Survey (BDHS, 2011 and 2014). In total, 7921, 9183, 4746 and 4557 children were eligible for final analysis for MICS 2012, MICS 2019, BDHS 2011 and BDHS 2014, respectively. We created the outcome variable childhood diseases (fever, short, rapid breaths, cough, blood in stools, and diarrhea). Two types of outcome variables were considered. The first outcome a count variable and the second outcome a binary variable is created from the count. We considered confounding factors are the age and sex of the child, child ever been breastfed, size of child at birth and weight at birth, geographic location (division), mother's age education, and body mass index, religion, and wealth index quintile. We estimated crude and adjusted risk ratio (RR) using two count data analysis models (Poisson and negative binomial).

Results: We found the proportions of C-section were 17.1%, 19.1%, 23.3%, and 36.0%, for BDHS (2011), MICS (2012), BDHS (2014), and MICS (2019) data, respectively. In comparison with normal delivery, the children born with C-section was at an increased risk of developing childhood diseases [risk ratio (RR): 1.02, 95% confidence interval (CI): 0.92-1.14], (RR: 1.05, 95% CI: 1.02-1.08), (RR: 1.08, 95% CI: 0.97-1.19), and (RR: 1.16, 95% CI: 1.14-1.18), the adjusted RR was [adjusted risk ratio (ARR): 1.07, 95% CI: 0.95-1.20], (ARR: 1.01, 95% CI: 0.97-1.04), and (ARR: 1.15, 95% CI: 1.05-1.27), and (ARR: 1.14, 95% CI: 1.11-1.17) for BDHS 2011, MICS 2012, BDHS 2014, and MICS 2019, respectively.

Conclusion: In both surveys, we observed an elevated risk of developing childhood diseases. The results from the BDHS 2014 and MICS 2019 data showed a significant association between C-section and childhood diseases in Bangladesh. We recommend raising public awareness of the negative impact of unnecessary delivery of C-section in Bangladesh.

**Keywords:** Caesarean section; normal delivery; childhood disease; survey, MICS, BDHS

**Introduction**

Cesarean delivery (C-section) is a surgical procedure that is often performed or recommended when the life of the mother or child is at risk [1]. Recently, it has become a preferred choice as a mode of delivery among women because they believed that it is painless, comfortable, safer, and healthier than normal delivery [2]. The unnecessary elective C-sections may increase harm on mother and child health [3].

The prevalence of the C-section is expeditiously growing in many developed and developing countries [4,5]. During the last decades, unnecessary C-sections increased rapidly from 6.7% in 1990 to 19.1% in 2014, this growth has been more severe in middle- and high-income countries than in developing countries [6]. It is increasing significantly, as evident more than half of the women voluntarily undergo C–section [7]. This choice is influenced by several non-medical reasons to women’s retrospective attitudes toward their social, cultural, and economic factors, including ways to prevent labor pain, it is safer, healthier than normal delivery [8], fear of normal delivery [9] and incorrect cultural assumptions [10], values [9], faster recovery after delivery [11], and financial shortage [12]. Besides, most women prefer C-section due to some medical reason for fetal causes, and fetomaternal causes, and closure of the uterine tubes [11].

A trend analysis based on data from 121 countries reported that, from 1990 to 2014, the average C-section rate increased by 12.4%, and it annually increased by 4.4% [13]. Furthermore, according to the latest data from 150 countries, the World Health Organization (WHO) survey recorded that the average global C-section rate was 18.6% of all C-section births, ranging from 1.4% to 56.4%. Latin America and the Caribbean currently have the highest C-section rates (40.5%), followed by North America (32.3%), Oceania (31.1%), Europe (25%), Asia (19.2%), and Africa (7.3%) [14]. As stated by WHO, there is no justification for any region to have a C-section rate higher than 10 -15%, which weighs a serious cause for concern in most of the countries worldwide [15]. In Bangladesh, the C-section rate increased from 3.5% in 2004 to 23% in 2014 [16].

There are several risks associated with the C-section for mother and those risk of health conditions, including cardiac arrest, hysterectomy, puerperal infection, thromboembolism, wound hematoma, anesthetics complications [17]. In addition, babies born in C-section are at risk of developing asthma, type 1 diabetes, allergic diseases [18,19], Crohn's disease [17], immune deficiencies, and leukemia. Bach [20] suggested that early life events (C-section) may be programming these diseases, as demonstrated by changes in disease prevalence in populations immigrating to westernized countries as chronic diseases such as asthma, allergy, inflammatory bowel disease, and type 1 diabetes have shown a parallel increase in prevalence during the last decades. Kristensen and Henriksen [21] also showed that delivery by C-section is associated with increased risk of disease in the offspring, such as neonatal respiratory morbidity, respiratory syncytial virus-induced hospitalization, bronchiolitis, asthma, gastroenteritis, inflammatory bowel disease, celiac disease, leukemia, and diabetes.

In Bangladesh, young children in general, are suffering from several common diseases such as fever, the difficulty of breathing, blood in stools, and diarrhea [22]. However, to the best of our knowledge, there is no published record that any research has been conducted to determine the association between C-section and early childhood diseases in Bangladesh. Therefore, it is important to study the consequence of C-section delivery on child health, particularly on early childhood diseases. To fill this gap in knowledge, we aimed to investigate the association between C-section and childhood diseases. We also explore other key factors associated with childhood diseases.

**Materials and Methods**

**Data sources and study design**

We used the latest available dataset from the Bangladesh Demographic and Health Survey (BDHS, 2011 and 2014) for our study. To compare and strengthen the association between C-section delivery and childhood diseases, we also used another parallel survey data, the multiple indicator cluster survey (MICS, 2012 and 2019) in Bangladesh. The BDHS is a large household survey produced by the Demographic and Health Surveys Program and the MICS is also a large, multi-dimensional household survey conducted by UNICEF. Both surveys highlighted on identical measures of fertility and child health, mortality, and indicators of access to maternal and child health interventions, illness, treatment, and nutritional status. Both surveys represent the seven administrative divisions (Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Barisal, and Khulna) of Bangladesh. These administrative divisions are taken as the main sampling strata for the sample [23,24]. Both datasets are fully open-access [25].

In BDHS 2011, information on 8753 mother-child pairs was collected. Out of the mother-child pairs, 474 children were excluded because they were death or not living with their mother. Moreover, as the BDHS 2011 data did not contain C-section information of greater than 3 years, 3533 children were omitted from the analysis. Hence, 4746 children were selected as a final sample for analysis (Fig 1).

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| **Fig 1. Flow Chart of BDHS 2011 data for the study population** |

In MICS 2012, information on 20356 mother-child pairs was collected. Out of the mother-child pairs, 2418 children were excluded because they were not living with their mother and some children were died after birth. Moreover, as the MICS 2012 data did not contain C-section information of greater than 3 years, 10017 children were excluded from the analysis. Thus, 7921 children were selected as a final sample for analysis (Fig 2).



**Fig 2. Flow Chart of MICS 2012 data for the study population**

In BDHS 2014, information on 7886 mother-child pairs was collected. Out of the mother-child pairs, 1236 children were excluded because they were death or not living with their mother. Moreover, as the BDHS data did not contain C-section information of greater than 3 years, 2093 children were omitted from the analysis. Hence, 4557 children were selected as a final sample for analysis (Fig 3).



**Fig 3. Flow Chart of BDHS 2014 data for the study population**

In MICS 2019, information on 24453 mother-child pairs was collected. Out of the mother-child pairs, 13819 children were excluded because they were not living with their mother and some children were died after birth. Moreover, as the MICS 2019 data did not contain C-section information of greater than 3 years, 1451 children were excluded from the analysis. Thus, 9183 children were selected as a final sample for analysis (Fig 4).

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**Fig 4. Flow Chart of MICS 2019 data for the study population**

**Outcome variable**

For creating the outcome variables, childhood disease, whether the child suffered from fever, short, rapid breaths, cough, blood in stools, and diarrhea in the two weeks before or during the survey. Two types of outcome variables were considered. The first outcome is a count variable that means the frequency of the diseases of the children (Fig 5) and the second outcome a binary variable is created from the count, if the number of diseases is less than median then outcome = 0, and median and more = 1. In the absence of a prior cut point, the most common approach is to take the sample median, the median value has been widely used in many studies as cut-points [26,27]. Median splits are one of the examples of "artificial categorization ", which refers to a more general process of defining classified variables based on the values ​​of many variables, which we have used in our research [28].

**Exposure variable**

The exposure variable was the type of delivery (C-section versus normal delivery), which is a binary variable.

**Potential confounding variables**

We considered important confounding variables and/or covariates are religion, breastfeeding status, child’s sex, age of mother and child, size of child at birth, the weight of the child at birth, mother’s education, mother’s education, mother’s body mass index, wealth index quintile, place of residence and geographic location (division).

**Statistical analyses**

**Descriptive statistics**

Descriptive statistics of each of the selected confounding variables and distribution of type of delivery were shown by adjusting for the sampling weight of the survey. Similarly, weighted percentages were calculated to compare demographic and socioeconomic characteristics among the type of delivery. Pearson's chi-squared test was used to determine whether differences in demographic and socioeconomic characteristics between C-section and normal delivery were statistically significant.

**Poisson regression models**

As our main outcome is a count variable, frequency of diseases,Poisson regression models were applied. It is used to study the association between count outcomes and covariates. The probability mass function for the Poisson is given by-

In Poisson model “y” distributed Poisson with variance function *Var(y)* = μ. The conditional variance as a function of the conditional mean is given in general form by φμ, with dispersion parameter φ. If φ = 1 then there is equidispersion; if φ < 1 there is underdispersion; and if φ > 1 there is overdispersion in the model [29].

**Identifying dispersion and scale adjustment**

Poison regression assumes that conditional means must be equal to the conditional variance. In fact, the data is more variable than is considered for under the Poison model. Thus, this equal dispersion assumption often does not hold true with real data. Under the Poison model, the unequal conditional variance of the data than its mean lead dispersion, which may be due to population heterogeneity, correlation, the omission of important covariates in the model, presence of outliers, zero inflation, or other reasons [30].

In this study, to test the dispersion of the Poisson model, dispersion parameters were considered. Thus, we tested the dispersion parameters of the model by adjusting Pearson's chi-square deviance and then fit the data with a negative binomial (NB) regression model. NB regression accounts for overdispersion by adding the dispersion parameter to the Poisson model. This model can accommodate increased variability [32]. We also applied the NB regression method with a log link. In the analyses, we reported crude (only exposure and outcome in the model) and adjusted (exposure and other confounding variables in the model) exposure effects.

**Model assessment**

We used the AIC and BIC values to compare the models (Poisson regression versus NB regression); the lowest value of AIC and BIC indicates a better fit of the data after accounting for model complexity (i.e., the number of model parameters). Using the best model, we reviewed the variability of the results from the models.

**Propensity score models**

As a sensitivity analysis, we also applied a propensity score (PS) method for the second outcome (binary) variable. The propensity score method is the probability of exposure (C-section versus normal delivery) assignment conditional on possible confounding variables. This approach helps us to design and analyze our observational survey data so that it mimics some of the characteristics (covariates) of a randomized controlled trial [34]. The detailed practical explanations of the PS method can be found elsewhere [34,35].

All statistical analyses were performed by SAS and SPSS (IBM SPSS 25). All data processing and cleaning were done by SPSS and in SAS, the survey analysis procedures command (e.g. PROC SURVEYFREQ, SURVEYLOGISTIC) were used to allow for the adjustments of the complex sampling design.

**Ethics approval**

Our study was wholly based on an analysis of existing public domain health survey datasets obtained from the BDHS 2011, 2014 and MICS 2012, 2019, which is freely available online with all personal identifying information removed. The BDHS data were reviewed and approved by the ICF Macro Institutional Review Board and the National Research Ethics Committee of the Bangladesh Medical Research Council. The MICS procedures were reviewed and approved by the Bangladesh Bureau of Statistics (BBS) and UNICEF. Informed consent was obtained from participants while interviewing them. Because this study involved the analysis with public access secondary data, thus, it does not require the approval of the respective institution.

**Results**

Our analyses showed that the proportions of C-section were 17.1%, 19.1%, 23.3%, and 36.0%, for BDHS (2011), MICS (2012), BDHS (2014), and MICS (2019) data, respectively (Fig 5).

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| **Fig 5. Trend of C-section in Bangladesh, 2011-2019** |

Moreover, for both MICS surveys, most of the children suffering from 2-3 diseases (about 72% for 2012 and 82% for 2019) in the two weeks before or during the survey and which is more noticeable in the C-section group. However, in BDHS 2011 and 2014, this percentage was only 34.3 and 29%, respectively, and almost equal between the two delivery groups Table 1. These findings indicate that there was a different trend for disease counts in MICS and BDHS surveys (Fig 6).

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| **Fig 6. Count (diseases) variable** |

Table 1 outlines the maternal and child characteristics between C-section and normal delivery for three databases. The mean age of mothers was about 25 years, and for all age groups, the distribution of the mothers between C-section and normal delivery was approximately similar. Mothers living in urban areas or belong to the richest family being delivered by C-section were significantly higher in all databases. Moreover, the education of mothers was significantly related to the C-section and the percentage was higher for the mothers with secondary or higher education. For example, for MICS 2019, about 84% (vs. 60% normal delivery) mother gave birth in C-section. Although the large size of the child at birth is one of the reasons for C-section, the highest percentage was observed for the average size of the child at birth in all databases (66.5% for BDHS 2011, 59.4% for MICS 2012, 66.8% for MICS 2019 and BDHS 2014).

**Table 1. Distribution of maternal and child characteristics including diseases count with the type of delivery**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
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| **Characteristics** | **BDHS 2011** | | | **MICS 2012** | | | **BDHS 2014** | | | **MICS 2019** | | |
| **Type of Delivery** | | | **Type of Delivery** | | | **Type of Delivery** | | | **Type of Delivery** | | |
| **Caesarean**  **(N=815)**  **n (%)** | **Normal**  **(N=3931)**  **n (%)** | **p-value** | **Caesarean**  **(N=1513)**  **n (%)** | **Normal (N=6408)**  **n (%)** | **p-value** | **Caesarean**  **(N=1062)**  **n (%)** | **Normal**  **(N=3495)**  **n (%)** | **p-value** | **Caesarean**  **(N=3306)**  **n (%)** | **Normal**  **(N=5877)**  **n (%)** | **p-value** |
| **Disease Count** |  |  |  |  |  |  |  |  |  |  |  |  |
| 0 (No) | 354 (41.3) | 1451 (37.3) | 0.002 | 20 (1.5) | 80 (1.2) | <0.001 | 518 (48.8) | 1813 (51.9) | <0.001 | 13 (0.4) | 39 (0.7) | <0.001 |
| 1 | 211 (24.6) | 847 (21.8) |  | 135 (10.1) | 981 (15.1) |  | 245 (23.1) | 607 (17.4) |  | 333 (10.1) | 583 (10.1) |  |
| 2 | 136 (15.9) | 775 (19.9) |  | 505 (37.6) | 2434 (37.5) |  | 162 (15.3) | 535 (15.3) |  | 823 (25.0) | 3486 (60.2) |  |
| 3 | 123 (14.4) | 596 (15.3) |  | 497 (37.0) | 2241 (34.5) |  | 122 (11.5) | 493 (14.1) |  | 1884 (57.3) | 1259 (21.7) |  |
| 4 | 33 (3.9) | 222 (5.7) |  | 137 (10.2) | 559 (8.6) |  | 15 (1.4) | 47 (1.3) |  | 220 (6.7) | 378 (6.5) |  |
| 5 | - | - |  | 49 (3.6) | 195 (3.0) |  | - | - |  | 16 (0.5) | 44 (0.8) |  |
| **Mother’s age group in years at birth** |  |  |  |  |  |  |  |  |  |  |  |  |
| Mean (SD) | 24.68 (5.3) | 24.26 (5.6) | 0.045 | 25.4 (5.2) | 25.9 (6.0) | <0.001 | 24.9 (5.5) | 24.5 (5.8) | 0.038 | 25.4 (5.3) | 25.7 (5.7) | <0.009 |
| 15-19 | 124 (15.2) | 807 (20.5) | <0.001 | 171 (11.4) | 740 (11.6) | <0.001 | 191 (18.0) | 745 (21.3) | 0.402 | 427 (13.0) | 812 (14.0) | <0.001 |
| 20-34 | 651 (79.9) | 2911 (74.1) |  | 1241(82.5) | 4952 (77.5) |  | 802 (75.5) | 2550 (73.0) |  | 2682 (81.5) | 4481 (77.4) |  |
| 35+ | 40 (4.9) | 213 (5.4) |  | 93 (6.1) | 700 (10.9) |  | 69 (6.5) | 200 (5.7) |  | 180 (5.5) | 497 (8.6) |  |
| **Religion** |  |  |  |  |  |  |  |  |  |  |  |  |
| Islam | 714 (87.7) | 3617 (92.0) | <0.001 | 1343 (88.9) | 5894 (92.2) | <0.001 | 961 (90.5) | 3236 (92.6) | 0.705 | 2955 (89.8) | 5373 (92.8) | <0.001 |
| Othersa | 100 (12.3) | 315 (8.0) |  | 167 (11.1) | 497 (7.8) |  | 101 (9.5) | 259 (7.4) |  | 334 (10.2) | 416 (7.2) |  |
| **Place of residence** |  |  |  |  |  |  |  |  |  |  |  |  |
| Urban | 316 (38.8) | 760 (19.3) | <0.001 | 548 (36.3) | 1110 (17.4) | <0.001 | 532 (50.1) | 925 (26.5) | <0.001 | 952 (28.9) | 1029 (17.8) | <0.001 |
| Rural | 498 (61.2) | 3172 (80.7) |  | 962 (63.7) | 5282 (82.6) |  | 530 (49.9) | 2570 (73.5) |  | 2337 (71.1) | 4760 (82.2) |  |
| **Geographic location** |  |  |  |  |  |  |  |  |  |  |  |  |
| Barishal | 34 (4.2) | 221 (5.6) | <0.001 | 50 (3.3) | 428 (6.7) | <0.001 | 105 (9.9) | 435 (12.4) | <0.001 | 374 (6.5) | 134 (4.1) | <0.001 |
| Chattogram | 162 (19.9) | 980 (24.9) |  | 267 (17.7) | 1577 (24.7) |  | 169 (15.9) | 716 (20.5) |  | 1391 (24.0) | 589 (17.9) |  |
| Dhaka | 292 (35.9) | 1148 (29.2) |  | 604 (40.0) | 1872 (29.3) |  | 262 (24.7) | 548 (15.7) |  | 1157 (20.0) | 1027 (31.2) |  |
| Khulna | 117 (14.4) | 331 (8.4) |  | 230 (15.2) | 524 (8.2) |  | 182 (17.1) | 346 (9.9) |  | 429 (7.4) | 480 (14.6) |  |
| Mymenshing | - | - |  | - | - |  | - | - |  | 543 (9.4) | 158 (4.8) |  |
| Rajshahi | 108 (13.3) | 509 (13.0) |  | 189 (12.5) | 656 (10.3) |  | 148 (13.9) | 406 (11.6) |  | 610 (10.5) | 429 (13.0) |  |
| Rangpur | 57 (7.0) | 431 (11.0) |  | 104 (6.9) | 788 (12.3) |  | 108 (10.2) | 440 (12.6) |  | 650 (11.2) | 319 (9.7) |  |
| Sylhet | 44 (5.4) | 310 (7.9) |  | 66 (4.4) | 547 (8.6) |  | 88 (8.3) | 604 (17.3) |  | 636 (11.0) | 153 (4.7) |  |
| **Mother’s education** |  |  |  |  |  |  |  |  |  |  |  |  |
| None | 39 (4.8) | 808 (20.5) | <0.001 | 80 (5.3) | 1378 (21.6) | <0.001 | 43 (4.0) | 571 (16.4) | <0.001 | 102 (3.1) | 673 (11.6) | <0.001 |
| Primary incomplete | - | - |  | 78 (5.2) | 964 (15.1) |  | - | - |  | - | - |  |
| Primary | 125 (15.4) | 1299 (33.0) |  | 142 (9.5) | 1096 (17.1) |  | 145 (13.7) | 1112 (31.8) |  | 419 (12.7) | 1646 (28.4) |  |
| Secondary incomplete | 441 (54.2) | 1680 (42.7) |  | 660 (44.0) | 2360 (36.9) |  | 572 (53.9) | 1580 (45.2) |  | - | - |  |
| Secondary complete/ higher | 209 (25.7) | 145 (3.7) |  | 539 (36.0) | 594 (9.3) |  | 302 (28.4) | 232 (6.6) |  | 2768 (84.2) | 3471 (60.0) |  |
| **Wealth index** |  |  |  |  |  |  |  |  |  |  |  |  |
| Richest | 29 (3.6) | 1059 (26.9) | <0.001 | 735 (48.6) | 847 (13.3) | <0.001 | 471 (44.4) | 437 (12.5) | <0.001 | 1172 (35.6) | 1654 (28.6) | <0.001 |
| Richer | 91 (11.2) | 864 (22.0) |  | 351 (23.2) | 1046 (16.5) |  | 275 (25.9) | 673 (19.3) |  | 800 (24.3) | 1275 (22.0) |  |
| Middle | 129 (15.8) | 803 (20.4) |  | 192 (12.7) | 1308 (20.6) |  | 165 (15.5) | 709 (20.3) |  | 622 (18.9) | 1094 (18.9) |  |
| Poorer | 208 (25.6) | 711 (18.1) |  | 136 (9.0) | 1436 (22.6) |  | 99 (9.3) | 763 (21.8) |  | 438 (13.3) | 996 (17.2) |  |
| Poorest | 357 (43.9) | 496 (12.6) |  | 98 (6.5) | 1717 (27.0) |  | 52 (4.9) | 913 (26.1) |  | 257 (7.8) | 770 (13.3) |  |
| **Body mass index (mother)** |  |  |  |  |  |  |  |  |  |  |  |  |
| Underweight | 132 (16.7) | 1243 (32.4) | <0.001 | 50 (3.3) | 320 (5.0) | <0.001 | 153 (14.5) | 1005 (28.9) | <0.001 | 151 (4.6) | 309 (5.3) | <0.001 |
| Normal | 453 (57.3) | 2345 (61.0) |  | 1034 (68.4) | 4934 (77.2) |  | 568 (53.7) | 2051 (58.9) |  | 2221 (67.5) | 4283 (74.0) |  |
| Overweight | 205 (25.9) | 254 (6.6) |  | 427 (28.3) | 1138 (17.8) |  | 336 (31.8) | 426 (12.2) |  | 917 (27.9) | 1197 (20.7) |  |
| **Breastfeeding status** |  |  |  |  |  |  |  |  |  |  |  |  |
| Yes | 691 (84.8) | 3447 (87.7) | 0.024 | 1483 (98.2) | 6208 (97.1) | 0.020 | 891 (83.9) | 3011 (86.1) | 0.018 | 3273 (99.5) | 5769 (99.6) | 0.374 |
| No | 124 (15.2) | 484 (12.3) |  | 27 (1.8) | 183 (2.9) |  | 171 (16.1) | 484 (13.9) |  | 16 (0.5) | 21 (0.4) |  |
| **Sex of the children** |  |  |  |  |  |  |  |  |  |  |  |  |
| Male | 432 (53.1) | 1958 (49.8) | 0.090 | 784 (51.9) | 3226 (50.5) | 0.331 | 575 (54.1) | 1768 (50.6) | 0.205 | 1758 (53.5) | 2914 (50.3) | 0.004 |
| Female | 382 (46.9) | 1973 (50.2) |  | 727 (48.1) | 3166 (49.5) |  | 487 (45.9) | 1727 (49.4) |  | 1531 (46.5) | 2876 (49.7) |  |
| **Child’s age group in months** |  |  |  |  |  |  |  |  |  |  |  |  |
| 0-11 | 311 (38.2) | 1362 (34.6) | 0.038 | 766 (50.7) | 3138 (49.1) | 0.264 | 372 (35.0) | 1090 (31.2) | 0.168 | 1677 (51.0) | 2688 (46.4) | <0.001 |
| 12-23 | 270 (33.2) | 1272 (32.4) |  | 744 (49.3) | 3254 (50.9) |  | 375 (35.3) | 1182 (33.8) |  | 1450 (44.1) | 2702 (46.7) |  |
| 24-35 | 233 (28.6) | 1297 (33.0) |  | - | - |  | 315 (29.7) | 1223 (35.0) |  | 161 (4.9) | 400 (6.9) |  |
| **Size at birth** |  |  |  |  |  |  |  |  |  |  |  |  |
| Very large | 16 (2.0) | 69 (1.8) | 0.111 | 5 (0.3) | 6 (0.1) | <0.001 | 23 (2.2) | 78 (2.2) | 0.009 | 60 (1.8) | 53 (0.9) | <0.001 |
| Larger than average | 118 (14.5) | 446 (11.3) |  | 326 (22.0) | 718 (12.2) |  | 154 (14.5) | 327 (9.4) |  | 435 (13.3) | 479 (8.4) |  |
| Average | 541 (66.5) | 2703 (68.8) |  | 881 (59.4) | 3794 (64.6) |  | 710 (66.8) | 2379 (68.1) |  | 2188 (66.8) | 4089 (71.4) |  |
| Smaller than average | 95 (11.7) | 514 (13.1) |  | 228 (15.4) | 1134 (19.3) |  | 118 (11.1) | 480 (13.7) |  | 933 (16.3) | 933 (16.3) |  |
| Very small | 44 (5.4) | 199 (5.1) |  | 44 (3.0) | 222 (3.8) |  | 57 (5.4) | 230 (6.6) |  | 173 (3.0) | 173 (3.0) |  |
| **Weight at birth** |  |  |  |  |  |  |  |  |  |  |  |  |
| Low | - | - |  | 306 (22.8) | 560 (37.0) | <0.001 | - | - | - | 2292 (73.2) | 1080 (66.6) | <0.001 |
| Normal | - | - |  | 1037 (77.2) | 952 (63.0) |  | - | - |  | 838 (26.8) | 541 (33.4) |  |

aOthers: Hinduism, Buddhism, Christianity

**Identifying overdispersion**

In BDHS (2011), MICS (2012), BDHS (2014) and MICS (2019), the value of dispersion parameters were 1.26, 1.08, 1.15 and 1.06, respectively. These dispersion parameters greater than one indicate that data were over-dispersed and that the Poisson regression model should be rejected in favor of the NB regression models.

**Model assessment**

Table 2 demonstrates the goodness of fit of two models, Poisson and NB regression. The NB model has the smallest AIC and BIC in all data sets, and therefore, it was chosen as a final model.

**Table 2. Model selection criteria for Poisson and NB model**

|  |  |  |  |
| --- | --- | --- | --- |
| **Data** | **Model** | **AICb** | **BICc** |
| **BDHS (2011)** | Poisson | 17392.62 | 17405.55 |
| **NBa** | **16259.17** | **16278.56** |
| **MICS (2012)** | Poisson | 24684.24 | 24698.17 |
| **NBa** | **24610.48** | **24621.38** |
| **BDHS (2014)** | Poisson | 13348.55 | 13361.40 |
| **NBa** | **12565.08** | **12584.35** |
| **MICS (2019)** | Poisson | 27400.02 | 27421.40 |
| **NBa** | **27165.02** | **27179.27** |

aNB: Negative Binomial,

bAIC: Akaike information criterion,

cBIC: Bayesian information criterion

Table 3 shows the results from crude and adjusted estimates obtained from the NB regression model. The analyses showed that the risk ratio (RR) for the C-section (vs normal delivery) was [risk ratio (RR): 1.02, 95% confidence interval (CI): 0.92-1.14] for BDHS 2011, (RR: 1.05, 95% CI: 1.02-1.08) for MICS 2012, (RR: 1.08, 95% CI: 0.97-1.19) for BDHS 2014 and (RR: 1.16, 95% CI: 1.14-1.18) for MICS 2019, respectively, which indicates that children were born in C-section compared with the normal delivery were at increased risk for developing childhood disease. The association was statistically significant for both MICS data (p-value=0.001), but for BDHS, this was not significant (p-value>0.05) in the crude model. Moreover, after adjusting for possible confounding factors in the adjusted NB model, the RR for developing childhood diseases was [adjusted risk ratio (ARR): 1.07, 95% CI: 0.95-1.20] for BDHS 2011, (ARR: 1.01, 95% CI: 0.97-1.04) for MICS 2012, (ARR: 1.15, 95% CI: 1.05-1.27) for BDHS 2014 and (ARR: 1.14, 95% CI: 1.11-1.17) for MICS 2019, respectively. Here, the association between C-section and childhood disease was statistically significant only for MICS 2019 (P<0.001) and BDHS 2014 data (P=0.004).

**Table 3. Association between C-section (vs normal delivery) and common childhood diseases from the crude and adjusted NB models**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Exposure** | **BDHS 2011** | | **MICS 2012** | | **BDHS 2014** | | **MICS 2019** | |
| **RRa (95% CI)** | **p-value** | **RRa (95% CI)** | **p-value** | **RRa (95% CI)** | **p-value** | **RRa (95% CI)** | **p-value** |
| **Crude Model** | C-section vs.  normal delivery | 1.02  (0.92-1.14) | 0.674 | 1.05  (1.02-1.08) | <0.001 | 1.08  (0.97-1.19) | 0.159 | 1.16  (1.14-1.18) | <0.001 |
| **Adjusted Modelb** | C-section vs.  normal delivery | 1.07  (0.95 - 1.20) | 0.245 | 1.01  (0.97-1.04) | 0.071 | 1.15  (1.05 - 1.27) | 0.004 | 1.14  (1.11 - 1.17) | <0.001 |

aRR: Risk Ratio,

bModel adjusted for possible confounding factors

Similarly, for the binary outcome, the crude estimates from the PS method, the risk of developing childhood diseases for C-section delivery were (RR: 1.02, 95% CI: 0.92-1.14), (RR: 1.12, 95% CI: 0.94-1.31), (RR: 1.11, 95% CI: 1.01-1.23) and (RR: 1.02, 95% CI: 0.87-1.20) for BDHS 2011, MICS 2012, BDHS 2014 and MICS 2019, respectively. The RR from adjusted (type of delivery and propensity scores) model was (ARR: 1.01, 95% CI: 0.91-1.13) for BDHS 2011, (ARR: 1.02, 95% CI: 0.90-1.14) for MICS 2012, (ARR: 1.17, 95% CI: 1.05-1.29) for BDHS 2014 and (ARR: 1.01, 95% CI: 0.98-1.03) for MICS 2019, respectively. Like negative binomial model, the association between C-section and childhood disease was statistically significant only for BDHS 2014 data in both models Table 4.

**Table 4. Association between C-section (vs normal delivery) and common childhood diseases from crude and adjusted PS models**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Model** | **Exposure** | **BDHS 2011** | | **MICS 2012** | | **BDHS 2014** | | **MICS 2019** | |
| **ARR (95% CI)** | **p-value** | **ARR (95% CI)** | **p-value** | **ARR (95% CI)** | **p-value** | **ARR (95% CI)** | **p-value** |
| **Crude Model** | C-section vs.  Normal delivery | 1.02  (0.92-1.14) | 0.674 | 1.12  (0.94-1.31) | 0.201 | 1.11  (1.01-1.23) | 0.042 | 1.02  (0.87-1.20) | 0.080 |
| **Adjusted Model** | C-section vs.  Normal delivery | 1.01  (0.91-1.13) | 0.864 | 1.02  (0.90-1.14) | 0.082 | 1.17  (1.05-1.29) | 0.030 | 1.01  (0.98-1.03) | 0.075 |

**Risk factors for childhood diseases**

Apart from the type of delivery, we observed that age of mother, geographic location, and BMI were significantly associated with childhood diseases in MICS 2012 and 2019 data. Moreover, BMI, sex of child, and child age were the contributing factors to childhood diseases according to BDHS data S1 and S2 Tables.

S3 Table shows the association between early childhood diseases and other confounding factors. Children from young mothers, aged between 15-19 years, were more affected by diseases, (ARR: 1.04, 95% CI: 0.97-1.12) for MICS 2012 and (ARR: 1.05, 95% CI: 0.95-1.15) for BDHS 2014, than those of other categories of ages. However, this association was not statistically significant. Moreover, children who were born to underweight and overweight mothers were more likely to have the disease, (ARR: 1.11, 95% CI: 1.04-1.19) and (ARR: 1.12, 95% CI: 1.03-1.21) in MICS 2012 and (ARR: 1.13, 95% CI: 1.01-1.26) and (ARR: 1.17, 95% CI: 1.03-1.32) in BDHS 2014. We found the age of the children was one of the important factors for childhood diseases in BDHS 2014 but not in MICS, and the results showed that children with age between 0-11 months and 12-23 months were more at risk of suffering from diseases than 24–35 months, (ARR: 1.15, 95% CI: 1.04-1.27), and (ARR: 1.14, 95% CI: 1.04-1.26).

**Discussion**

In this study, we investigated the relationship between C-section (versus normal delivery) and early childhood diseases in Bangladesh using multiple nationally representative surveys. We observed that for BDHS (2011), MICS (2012), BDHS (2014) and MICS (2019), the percentage of C-section were 17.1 percent, 19.1 percent, 23.3 percent, and 36.0 percent, respectively, and it continued to increase gradually. While the trend towards C-section is rising over time, there is a significant disparity between databases. We found that the risk of childhood diseases for children born in C-section was substantially higher than children in normal delivery. This finding over the databases is consistent. In addition to the C-section, we have found that in all databases, the body mass index of the mother was a major risk factor for childhood diseases. In addition, in both MICS databases, geographic location, and weight at the child's birth were reported as other significant risk factors for childhood diseases. Furthermore, only for the BDHS database, sex of the child and child age were substantially correlated with the diseases.

Children born in C-section may have a poor immune system relative to regular delivery children due to lack of interaction with maternal gut bacteria [36,37]. They mostly had bacteria associated with hospital environments in their guts, which may have a negative impact on their health [36,37]. In addition, mothers who opted to go through C-section were usually exposed to multiple medications, including antibiotics and painkillers during pregnancy and/or after birth, which may have a long-term negative effect on children's health and some of the microbiome discrepancies from the children born in normal delivery [36]. Furthermore, available epidemiological data have shown that many diseases (e.g., type I diabetes mellitus, extreme respiratory morbidity, celiac disease) including atopic disease occur more often in infants after C-section than after vaginal delivery [36–43]. Several studies also indicated that due to delay onset of lactation in the C-section, many infants may receive bottle milk and may developed diarrheal diseases [44,45].

From our findings, indicated that the delivery rate for the C-section was higher particularly in the Dhaka division compared to other divisions in Bangladesh. The heterogeneous socioeconomic status and women’s education in the regions of Chittagong, Dhaka, Khulna and Rajshahi were high. It is evident that that women in those divisions were more likely to benefit from hospital delivery to choose C-section [46]. For instance, the risk of disease was higher in Khulna in the MICS survey. Most of the women in these areas are educated and they belong to middle-class and rich families, and have access to and ability to undergo CS delivery [47]. Nowadays educated pregnant women want to avoid vaginal delivery in fear of labor pain and other conveniences [48]. Perhaps these are the most important reasons for the increased rate of CS delivery in Bangladesh.

Our study findings also confirmed that the highest rate of C-section among educated women has occurred among secondary completed or higher educated females. We also observed that there was a lower risk of disease for babies in the C-section than children born through normal delivery in all other mother's education levels compared to this group. Since education is directly related to women's autonomy, they are more economically solvent and may decide to give birth through a C-section, mostly living in urban areas. Some studies, however, reported no visible link between women's preference for C-section and their educational level [49,50]. By wealth status, for the richest family, health care facilities were higher than for the middle and poorer families. C-section rates were also higher among the wealthiest families compared with those of the poorest or poorest families [51]. This could be because of financial problems, because the richest family has the ability to bear C-section expenses.

The analyses of this study confirmed that childhood disease is associated with maternal age, according to MICS data. In earlier, a study showed that children born to younger mothers (aged <20 years) were found to have a relatively high risk of diarrhea, cough, and fever. [52], probably because the relationship between maternal age is associated with some adverse pregnancy outcomes and a higher risk of medical conditions such as hypertension, diabetes, or other causes. However, in the BDHS data, there was no clear and consistent relationship between the ages of the mothers and the risk of short-term diseases.

The study involved a high-quality, nationally representative large data set from three household surveys, with high response rate. However, there are some limitations of the study. Data used in this study were retrospective response for the women having at least one child that she recalls of type of delivery and diseases of her child. Many diseases might not had been in a position to recall correctly. Therefore, the main limitation of this study was recall bias. Another limitation of those data was that, they do not include a systematic medical assessment of the ill child, physical exam, laboratory records and include only specific disease information with recall method. This study included children based on the C-section information which included by the survey. For this reason, we included all such children from the household that participated in the study with different age. This may create selection bias in the direction of overestimating or underestimating.

**Conclusions**

In conclusion, our study shows C-section continued to increase gradually over time, and there is a significant positive association between C-section and early childhood diseases in Bangladesh. The analysis also confirmed that childhood disease is associated with maternal age. Among the educated women, the highest C-section rate has occurred among secondary completed or higher educated women. Rates of C-section were also higher among the wealthiest family than those belonging to the poorest or poorer families. As the unnecessary C-section is a burden on the health system and negatively affects childhood health, improving maternal health requires regular monitoring and evaluation of the provision of emergency obstetric services. Thus, the decision to perform a C-section delivery must be carefully chosen and not aimed at profit.

**Recommendations**

The increasing C-section birth may have negative effects on early childhood diseases, poor immune system and the infant-mother relationship. C-section also responsible for many diseases (e.g., type I diabetes mellitus, extreme respiratory morbidity, leukemia, celiac, malignancies and allergic disease) including atopic disease occur more often in infants after C-section. The negative impacts of C-section on later health may be due to the delay in the postnatal establishment of the gut microbiota and subsequent alterations to the maturation of the mucosal immune system. However, to reduce unnecessary C-sections and reduce complicated health impact, various strategies must be taken, such as the implementation of standardized protocols [53], requests of a second medical opinion prior to surgery [14], improving maternal empowerment during pregnancy and delivery [54], maternal and medical collaboration on birth plans. Prior to delivery, all available birthing procedures and its merit and demerit should be explained to the pregnant women during the antenatal care period. Further studies are needed to enrich our knowledge on the negative impact of C-section delivery and its association with the development of childhood disease, the incidence of the chronic immune system and metabolic disorders in developing countries including Bangladesh. However, we recommend increasing public awareness campaign for negative impact of unnecessary C-section on children’s adverse health outcomes.

**Acknowledgments**

Data used in this study has been collected from BDHS and MICS database. The authors thank BDHS and MICS for granting permission to use the data. The authors also acknowledge the support of Department of Statistics, Shahjalal University of Science and Technology, Bangladesh, where this study was conducted.

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