**Association between cesarean delivery and early childhood diseases in Bangladesh**

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**Abstract**

Introduction: 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 health consequences of 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, 2014). In total, 7921, 9183, and 4557 children were eligible for final analysis for MICS 2012, MICS 2019, and BDHS, respectively. We created the outcome variable childhood diseases ( fever, short, rapid breaths, cough, blood in stools, and diarrhea). 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, geographical location, mother's age education, and body mass index, the religion of household head, and wealth index quintile. We estimated crude and adjusted risk ratio (RR) using different count data analysis models (e.g., negative binomial).

Results: We found the proportions of cesarean deliveries were 19.1%, 23.3%, and 36.0%, for MICS (2012), BDHS (2014), and MICS (2019) data, respectively. The crude RR for the C-section as compared with normal delivery was 1.05 (95% confidence interval (CI): 1.02-1.08), 1.08 (CI: 0.97-1.19), and 1.16 (CI: 1.14-1.18) for MICS 2012, BDHS 2014, and MICS 2019, respectively. The adjusted RR was 1.01 (95% CI: 0.97-1.04), 1.14 (CI: 1.11-1.17) for MICS 2012 and MICS 2019, respectively. For BDHS, the adjusted RR was 1.15 (CI:1.05-1.27).

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 cesarean delivery in Bangladesh.

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

**1. 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 (Zakerihamidi et al., 2015). 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 (Lori & Boyle, 2011). This choice may increase unnecessary C-section and harm the mother and child health (Haider et al., 2018).

The prevalence of the C-section is expeditiously growing in many developed and developing countries (Farmer et al., 2003; Gomes et al., 1999). During the last decades, unnecessary C-section has increased rapidly (Magne et al., 2017). It is increasing significantly, as evident more than half of the women voluntarily undergo C–section (Danforth & Gibbs, 2008). This choice is influenced by several factors, including ways to prevent labor pain, it is safer, healthier than normal delivery (Tatar et al., 2000), fear of normal delivery (Latifnejad-Roudsari et al., 2014), incorrect cultural assumptions (Aziken et al., 2007), and closure of the uterine tubes (Kasai et al., 2010). In contrast, most women prefer natural birth due to personal beliefs, cultural customs, and values (Latifnejad-Roudsari et al., 2014), faster recovery after delivery (Kasai et al., 2010), financial shortage (Zakerihamidi et al., 2014).

A trend analysis based on data from 121 countries reported that, from 1990 to 2014, the average C-section rates increased by 12.4%, and it annually increased by 4.4% (Betrán et al., 2016). Moreover, a 2004-2008 world health organization (WHO) survey recorded an average global rate of C-section was 25.7%, the rate was 27.3% in Asia, 29.2% in Latin America, and 19.0% in Europe (Lumbiganon et al., 2010; Villar et al., 2006). As stated by WHO, there is no justification for any region to have a cesarean rate higher than 10 -15%, which weighs a serious cause for concern in most of the countries worldwide (Rahman et al., 2015). In Bangladesh, the C-section rate increased from 3.5% in 2004 to 23% in 2014 (Khan et al., 2017).

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 (Yuan et al., 2016). In addition, babies born in C-section are at risk of developing asthma, type 1 diabetes, allergic diseases (Ajslev et al., 2011; Darmasseelane et al., 2014), Crohn's disease (Yuan et al., 2016), immune deficiencies, and leukemia. Rahman and colleagues (Rahman et al., 2015) showed that previous C-section, prolonged labor, higher maternal education level, mother age of 25 years or more, the lower order of birth, baby length greater than 45 cm, and unbalanced diet were some factors that were significantly associated with C-section. Another study found that higher the age of mother, lower birth order, higher education of parents, higher socioeconomic status, poor maternal history, and three or more antenatal cares was significantly associated with C-section delivery (Begum et al., 2017).

In Bangladesh, young children in general, are suffering from several common diseases such as fever, the difficulty of breathing, blood in stools, and diarrhea (Ferdous et al., 2018). 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 delivery and childhood diseases. We also explore key factors associated with childhood diseases.

**2. Methods**

***Data source and study design***

We used the latest available dataset from the Bangladesh Demographic and Health Survey (BDHS, 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 (MICS, 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 (MICS, 2015; Yun et al., 2013). Both datasets are fully open-access (Corsi et al., 2017).

In BDHS 2014, information on 7886 mother-child pairs was collected. Out of the mother-child pairs, 1236 children were excluded because they were 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 (Figure 1). Similarly, in MICS 2012, information on 59599 women was collected. Out of this number, 36197 women have not had a child, and 15481 babies greater than 24 months were excluded from the analysis. Therefore, the sample included 7921 mother-child pairs for analysis (Figure 2). 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 (Figure 3).

**Outcome variable**

For creating the outcome variables, childhood disease, we used several variables are 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. First, a count variable that means the frequency of the diseases of the children (figure 5); second, a binary outcome in which 0 means children were suffered from less than the median value of the count of diseases and 1 means greater- equal median value of the count disease.

**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 geographical 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 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. However, this model often displays overdispersion, for that reason, negative binomial (NB) regression models are appropriate and most convenient to use in the analyses (Lawless, 1987). Thus, 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.

**Propensity score models:** As a sensitivity, 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 (Austin, 2011). The detailed practical explanations of the PS method can be found elsewhere (Ali et al., 2016; Austin, 2011).

**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.

All statistical analyses were performed by SAS and SPSS (IBM SPSS 25). 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 2014 and MICS 2012, 2019, which is freely available online with all personal identifying information removed. The BDHS 2014 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.

**3. Results**

Our analyses showed that the proportions of cesarean deliveries were 19.1%, 23.3%, and 36.0%, for MICS (2012), BDHS (2014), and MICS (2019) data, respectively (Figure 4). 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, this percentage was only 29% 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 (Figure 5).

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 (59.4% for MICS 2012, 66.8% for MICS 2019 and BDHS 2014).

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 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 1.05 (95% confidence interval (CI): 1.02-1.08) for MICS 2012, 1.08 (CI: 0.97-1.19) for BDHS 2014 and 1.16 (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=0.159) in the crude model. Moreover, after adjusting for possible confounding factors in the adjusted NB model, the RR was 1.01 (95% CI: 0.97-1.04) for MICS 2012, 1.15 (CI: 1.05-1.27) for BDHS 2014 and 1.14 (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 data (P=0.004) (Table 3).

Similarly, for the binary outcome, the crude estimates from the PS method were 1.12 (95% CI: 0.94-1.31), 1.11 (95% CI: 1.01-1.23) and 1.02 (CI:0.87-1.20) for MICS 2012,BDHS 2014 and MICS 2019, respectively. The RR from adjusted (type of delivery and propensity scores) model was 1.02 (CI: 0.90-1.14) for MICS 2012, 1.17 (1.05-1.29) for BDHS 2014 and 1.01 (CI: 98-1.03) for MICS 2019, respectively. Like NB binomial model, the association between C-section and childhood disease was statistically significant only for BDHS data in both models (Table 4).

**Risk factors for childhood diseases**

Apart from the type of delivery, we observed that age of mother, geographical 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 (Table S1 and S2).

Table S3 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, 1.04 (CI: 0.97-1.12) for MICS 2012 and 1.05 [0.95-1.15] for BDHS, 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, 1.11 (CI: 1.04-1.19) and 1.12 (95 % CI: 1.03-1.21) in MICS 2012 and 1.13 (CI: 1.01-1.26) and 1.17 (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 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, 1.15 (CI: 1.04-1.27), and 1.14 (CI: 1.04-1.26).

**4. 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 MICS (2012), BDHS (2014) and MICS (2019), the percentage of cesarean deliveries was 19.1 percent, 23.3 percent, and 36.0 percent, respectively, and it continued to increase gradually. While the trend towards cesarean delivery 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 cesarean delivery may have a poor immune system relative to regular delivery children due to lack of interaction with maternal gut bacteria (Biasucci et al., 2008; Shao et al., 2019). They mostly had bacteria associated with hospital environments in their guts, which may have a negative impact on their health (Biasucci et al., 2008; Shao et al., 2019). In addition, mothers who opted to go through cesarean delivery 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 (Shao et al., 2019). 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 cesarean delivery than after vaginal delivery (Biasucci et al., 2008; Debley et al., 2005; Decker et al., 2010; Eggesbø et al., 2003; Laubereau et al., 2004; Negele et al., 2004; Onkamo et al., 1999; Shao et al., 2019). Several studies also indicated that due to delay onset of lactation in the cesarean section, many infants may receive bottle milk and may developed diarrheal diseases (Hobbs et al., 2016; Stuebe, 2009).

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. An earlier study found that women in the division of Chittagong, Dhaka, Khulna and Rajshahi were more likely to benefit from hospital delivery and C-section (Kamal, 2013). 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 (Hasan et al., 2019). Now a day educated pregnant women want to avoid vaginal delivery in fear of labor pain and other conveniences. 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 (Angeja et al., 2006; Chu et al., 2010). 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 (Shahabuddin et al., 2016). 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. (Kandala, 2006), 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.

**Conclusion**

In conclusion, our study shows cesarean delivery 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 cesarean section delivery 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 cesarean birth may have negative effects on early childhood diseases, poor immune system and the infant-mother relationship. Cesarean delivery 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 cesarean delivery. 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, requests of a second medical opinion prior to surgery, improving maternal empowerment during pregnancy and delivery, 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 cesarean delivery on children’s adverse health outcomes.

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**TABLES AND FIGURES**



**Figure 1: Flow Chart of BDHS 2014 data for the study population**

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**Figure 3: Flow Chart of MICS 2019 data for the study population**

|  |  |  |
| --- | --- | --- |
|  |  |  |
| **Figure 4a: C-section delivery in MICS (2012)** | **Figure 4b: C-section delivery in BDHS (2014)** | **Figure 4c: C-section delivery in MICS (2019)** |
|  |  |  |
| **Figure 5a: Count (diseases) variable in MICS (2012)** | **Figure 5b: Count (diseases) variable in BDHS (2014)** | **Figure 5c: Count (diseases) variable in MICS (2019)** |

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

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **MICS 2012** | | | **BDHS 2014** | | | **MICS 2019** | | |
|  | **Type of Delivery** | | | **Type of Delivery** | | | **Type of Delivery** | | |
| **Sources** | **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) | 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 | 135 (10.1) | 981 (15.1) |  | 245 (23.1) | 607 (17.4) |  | 333 (10.1) | 583 (10.1) |  |
| 2 | 505 (37.6) | 2434 (37.5) |  | 162 (15.3) | 535 (15.3) |  | 823 (25.0) | 3486 (60.2) |  |
| 3 | 497 (37.0) | 2241 (34.5) |  | 122 (11.5) | 493 (14.1) |  | 1884 (57.3) | 1259 (21.7) |  |
| 4 | 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) | 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 | 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 | 1241(82.5) | 4952 (77.5) |  | 802 (75.5) | 2550 (73.0) |  | 2682 (81.5) | 4481 (77.4) |  |
| 35+ | 93 (6.1) | 700 (10.9) |  | 69 (6.5) | 200 (5.7) |  | 180 (5.5) | 497 (8.6) |  |
| **Religion** | | | | | | | | | |
| Islam | 1343 (88.9) | 5894 (92.2) | <0.001 | 961 (90.5) | 3236 (92.6) | 0.705 | 2955 (89.8) | 5373 (92.8) | <0.001 |
| Other\* | 167 (11.1) | 497 (7.8) |  | 101 (9.5) | 259 (7.4) |  | 334 (10.2) | 416 (7.2) |  |
| **Place of residence** | | | | | | | | | |
| Urban | 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 | 962 (63.7) | 5282 (82.6) |  | 530 (49.9) | 2570 (73.5) |  | 2337 (71.1) | 4760 (82.2) |  |
| **Geographical location** | | | | | | | | | |
| Barishal | 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 | 267 (17.7) | 1577 (24.7) |  | 169 (15.9) | 716 (20.5) |  | 1391 (24.0) | 589 (17.9) |  |
| Dhaka | 604 (40.0) | 1872 (29.3) |  | 262 (24.7) | 548 (15.7) |  | 1157 (20.0) | 1027 (31.2) |  |
| Khulna | 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 | 189 (12.5) | 656 (10.3) |  | 148 (13.9) | 406 (11.6) |  | 610 (10.5) | 429 (13.0) |  |
| Rangpur | 104 (6.9) | 788 (12.3) |  | 108 (10.2) | 440 (12.6) |  | 650 (11.2) | 319 (9.7) |  |
| Sylhet | 66 (4.4) | 547 (8.6) |  | 88 (8.3) | 604 (17.3) |  | 636 (11.0) | 153 (4.7) |  |
| **Mother’s education** | | | | | | | | | |
| None | 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 | 142 (9.5) | 1096 (17.1) |  | 145 (13.7) | 1112 (31.8) |  | 419 (12.7) | 1646 (28.4) |
| Secondary incomplete | 660 (44.0) | 2360 (36.9) |  | 572 (53.9) | 1580 (45.2) |  | - | - |
| Secondary complete/ higher | 539 (36.0) | 594 (9.3) |  | 302 (28.4) | 232 (6.6) |  | 2768 (84.2) | 3471 (60.0) |
| **Wealth index** | | | | | | | | | |
| Richest | 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 | 351 (23.2) | 1046 (16.5) |  | 275 (25.9) | 673 (19.3) |  | 800 (24.3) | 1275 (22.0) |  |
| Middle | 192 (12.7) | 1308 (20.6) |  | 165 (15.5) | 709 (20.3) |  | 622 (18.9) | 1094 (18.9) |  |
| Poorer | 136 (9.0) | 1436 (22.6) |  | 99 (9.3) | 763 (21.8) |  | 438 (13.3) | 996 (17.2) |  |
| Poorest | 98 (6.5) | 1717 (27.0) |  | 52 (4.9) | 913 (26.1) |  | 257 (7.8) | 770 (13.3) |  |
| **Body mass index (mother)** | | | | | | | | | |
| Underweight | 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 | 1034 (68.4) | 4934 (77.2) |  | 568 (53.7) | 2051 (58.9) |  | 2221 (67.5) | 4283 (74.0) |  |
| Overweight | 427 (28.3) | 1138 (17.8) |  | 336 (31.8) | 426 (12.2) |  | 917 (27.9) | 1197 (20.7) |  |
| **Breastfeeding status** | | | | | | | | | |
| Yes | 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 | 27 (1.8) | 183 (2.9) |  | 171 (16.1) | 484 (13.9) |  | 16 (0.5) | 21 (0.4) |  |
| **Sex of the children** | | | | | | | | | |
| Male | 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 | 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 | 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 | 744 (49.3) | 3254 (50.9) |  | 375 (35.3) | 1182 (33.8) |  | 1450 (44.1) | 2702 (46.7) |  |
| 24-35 | - | - |  | 315 (29.7) | 1223 (35.0) |  | 161 (4.9) | 400 (6.9) |  |
| **Size at birth** | | | | | | | | | |
| Very large | 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 | 326 (22.0) | 718 (12.2) |  | 154 (14.5) | 327 (9.4) |  | 435 (13.3) | 479 (8.4) |  |
| Average | 881 (59.4) | 3794 (64.6) |  | 710 (66.8) | 2379 (68.1) |  | 2188 (66.8) | 4089 (71.4) |  |
| Smaller than average | 228 (15.4) | 1134 (19.3) |  | 118 (11.1) | 480 (13.7) |  | 933 (16.3) | 933 (16.3) |  |
| Very small | 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) |  |

\*Hinduism, Buddhism, Christianity

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

|  |  |  |  |
| --- | --- | --- | --- |
| **Data** | **Model** | **AIC** | **BIC** |
| **MICS (2012)** | Poisson | 24684.24 | 24698.17 |
| **NB** | **24610.48** | **24621.38** |
| **BDHS (2014)** | Poisson | 13348.55 | 13361.40 |
| **NB** | **12565.08** | **12584.35** |
| **MICS (2019)** | Poisson | 27400.02 | 27421.40 |
| **NB** | **27165.02** | **27179.27** |

\*NB: Negative Binomial, AIC: Akaike information criterion, BIC: Bayesian information criterion

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

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **MICS 2012** | | **BDHS 2014** | | **MICS 2019** | |
| **Model** | **Exposure** | **RR (95% CI)** | **p-value** | **RR (95% CI)** | **p-value** | **RR (95% CI)** | **p-value** |
| **Crude Model** | C-section vs.  normal delivery | 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 Model\*** | C-section vs.  normal delivery | 1.01  (0.97-1.04) | 0.071 | 1.15  (1.05 - 1.27) | 0.004 | 1.14  (1.11 - 1.17) | <0.001 |

RR: Risk Ratio, NB: Negative Binomial, \*Model adjusted for possible confounding factors

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

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **MICS 2012** | | **BDHS 2014** | | **MICS 2019** | |
| **Model** | **Exposure** | **ARR (95% CI)** | **p-value** | **ARR (95% CI)** | **p-value** | **ARR (95% CI)** | **p-value** |
| **Crude Model** | C-section vs.  Normal delivery | 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 | 1.02  (0.90-1.14) | 0.082 | 1.17  (1.05-1.29) | 0.030 | 1.01  (0.98-1.03) | 0.075 |

PS: Propensity Scores

**SUPPLEMENTARY MATERIAL**

**Table S1: Unadjusted LR statistics for type 3 analysis**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **MICS 2012** | | **BDHS 2014** | | **MICS 2019** | |
| **Source** | **Chi-Square** | **P-value** | **Chi-Square** | **P-value** | **Chi-Square** | **P-value** |
| **Type of Delivery** | 11.58 | <0.001 | 1.88 | 0.170 | 226.75 | <0.001 |

**Table S2: Adjusted LR Statistics for Type 3 Analysis**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **MICS 2012** | | **BDHS 2014** | | **MICS 2019** | |
| **Covariates** | **Chi-Square** | **P-value** | **Chi-Square** | **P-value** | **Chi-Square** | **P-value** |
| **Type of Delivery** | 0.08 | **0.071** | 8.24 | **0.004** | 106.25 | **<0.001** |
| **Mother Age** | 10.87 | **0.004** | 2.06 | 0.357 | 0.51 | 0.775 |
| **Religion** | 2.50 | 0.114 | 0.62 | 0.429 | 0.75 | 0.387 |
| **Place of residence** | 0.00 | 0.989 | 0.00 | 0.969 | 0.01 | 0.905 |
| **Geographical Location** | 60.13 | **<0.001** | 9.48 | 0.148 | 91.56 | **<0.001** |
| **Mother's education** | 8.95 | 0.062 | 3.76 | 0.288 | 0.05 | 0.973 |
| **Wealth Index** | 3.21 | 0.524 | 5.71 | 0.222 | 4.26 | 0.372 |
| **Body Mass Index** | 8.93 | **0.012** | 6.41 | **0.041** | 6.64 | **0.036** |
| **Breastfeed** | 0.99 | 0.321 | 2.63 | 0.105 | 2.54 | 0.111 |
| **Sex of the children** | 1.65 | 0.199 | 4.26 | **0.039** | 0.06 | 0.808 |
| **Child age** | 0.55 | 0.459 | 9.71 | **0.008** | 3.23 | 0.199 |
| **Size at birth** | 5.54 | **0.236** | 7.63 | 0.106 | 4.39 | 0.356 |
| **Weight at birth** | 4.02 | **0.045** | - | - | 0.10 | 0.750 |

**Table S3: Influence of factors associated with childhood diseases (lower diseases and normal delivery vs. higher diseases due to C-section delivery)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sources** | **Adjusted Estimates** | | | | | | | | |
| **MICS 2012** | | | **BDHS 2014** | | | **MICS 2019** | | |
| **ARR\*** | **95% CI** | **p-value** | **ARR\*** | **95% CI** | **p-value** | **ARR\*** | **95% CI** | **p-value** |
| **Type of Delivery** | | | | | | | | | |
| C-section | 1.02 | 0.97-1.04 | 0.071 | 1.15 | 1.05 - 1.27 | 0.004 | 1.14 | 1.11-1.17 | <0.001 |
| Normal | 1 | - | - | 1 | - | - | 1 | - | - |
| **Mother’s age group in years at birth** | | | | | | | | | |
| 15-19 | 1.04 | 0.97-1.12 | 0.276 | 1.05 | 0.95-1.15 | 0.182 | 1.01 | 0.96-1.06 | 0.720 |
| 20-34 | 0.93 | 0.88-0.97 | 0.002 | 0.96 | 0.87-1.06 | 0.376 | 0.98 | 0.94-1.02 | 0.510 |
| 35+ | 1 | - | - | 1 | - | - | 1 | - | - |
| **Religion** | | | | | | | | | |
| Islam | 0.95 | 0.90-1.01 | 0.107 | 1.06 | 0.92-1.21 | 0.431 | 0.99 | 0.95-1.02 | 0.381 |
| Other religion (Hinduism, Buddhism, Christianity) | 1 | - | - | 1 | - | - | 1 | - | - |
| **Place of residence** | | | | | | | | | |
| Urban | 1.01 | 0.95-1.05 | 0.989 | 1.00 | 0.91-1.10 | 0.969 | 1.01 | 0.97-1.03 | 0.905 |
| Rural | 1 | - | - | 1 | - | - | 1 | - | - |
| **Geographical Location** | | | | | | | | | |
| Barishal | 0.94 | 0.82-1.08 | 0.486 | 1.00 | 0.85-1.17 | 0.981 | 0.94 | 0.90-0.99 | <0.001 |
| Chattogram | 0.90 | 0.81-0.99 | 0.037 | 1.07 | 0.94-1.22 | 0.319 | 0.88 | 0.84-0.92 | 0.017 |
| Dhaka | 0.90 | 0.82-0.99 | 0.029 | 0.94 | 0.82-1.07 | 0.339 | 0.95 | 0.90-1.01 | 0.420 |
| Khulna | 1.10 | 0.99-1.21 | 0.164 | 1.04 | 0.89-1.21 | 0.636 | 1.02 | 0.95-1.09 | 0.596 |
| Mymenshing | - | - | - | - | - | - | 0.99 | 0.94-1.04 | 0.719 |
| Rajshahi | 1.03 | 0.94-1.14 | 0.389 | 0.96 | 0.83-1.11 | 0.554 | 0.89 | 0.84-0.94 | 0.016 |
| Rangpur | 1.07 | 0.97-1.18 | 0.075 | 0.90 | 0.77-1.01 | 0.160 | 1.02 | 1.02-1.07 | <0.001 |
| Sylhet | 1 | - | - | 1 | - | - | 1 | - | - |
| **Educational level (mother)** | | | | | | | | | |
| None | 0.89 | 0.82-0.96 | 0.042 | 0.89 | 0.75-1.05 | 0.166 | 0.99 | 0.94-1.05 | 0.911 |
| Primary incomplete | 0.93 | 0.86-1.01 | 0.091 | 0.91 | 0.81-1.03 | 0.154 |
| Primary | 0.97 | 0.91-1.04 | 0.395 | 0.98 | 0.87-1.11 | 0.780 | 0.99 | 0.97-1.03 | 0.827 |
| Secondary incomplete | 0.98 | 0.92-1.03 | 0.336 | - | - | - | - | - | - |
| Secondary complete/higher | 1 | - | - | 1 | - | - | 1 | - | - |
| **Wealth Index** | | | | | | | | | |
| Richest | 1.04 | 0.99-1.10 | 0.259 | 1.17 | 1.03-1.34 | 0.191 | 1.03 | 0.98-1.07 | 0.574 |
| Richer | 1.03 | 0.98-1.09 | 0.150 | 1.10 | 0.95-1.28 | 0.119 | 1.02 | 0.97-1.05 | 0.555 |
| Middle | 1.02 | 0.96-1.09 | 0.494 | 1.11 | 0.96-1.28 | 0.148 | 1.01 | 0.96-1.02 | 0.249 |
| Poorer | 1.00 | 0.95-1.07 | 0.876 | 1.11 | 0.98-1.25 | 0.110 | 1.00 | 0.95-1.03 | 0.678 |
| Poorest | 1 | - | - | 1 | - | - | 1 | - | - |
| **Body Mass Index (mother)** | | | | | | | | | |
| Underweight | 1.11 | 1.04-1.19 | 0.002 | 1.13 | 1.01-1.26 | 0.025 | 1.05 | 1.01-1.09 | 0.027 |
| Overweight | 1.12 | 1.03-1.21 | 0.005 | 1.17 | 1.03-1.32 | 0.015 | 1.01 | 0.97-1.02 | 0.621 |
| Normal | 1 | - | - | 1 | - | - | 1 | - | - |
| **Breastfeeding status** | | | | | | | | | |
| Yes | 0.91 | 0.76-1.10 | 0.634 | 0.91 | 0.81-1.02 | 0.066 | 0.81 | 0.64-1.03 | 0.081 |
| No | 1 | - | - | 1 | - | - | 1 | - | - |
| **Sex of child** | | | | | | | | | |
| Male | 1.03 | 0.99-1.06 | 0.822 | 1.08 | 1.00-1.16 | 0.039 | 1.01 | 0.98-1.02 | 0.808 |
| Female | 1 | - | - | 1 | - | - | 1 | - | - |
| **Child’s age group in months** | | | | | | | | | |
| 0-11 | 1.02 | 0.98-1.06 | 0.459 | 1.15 | 1.04-1.27 | 0.006 | 1.03 | 0.98-1.08 | 0.199 |
| 12-23 | 1 | - | - | 1.14 | 1.04-1.26 | 0.005 | 1.02 | 0.97-1.07 | 0.521 |
| 24-35 | - | - | - | 1 | - | - | 1 | - | - |
| **Size at birth** | | | | | | | | | |
| Very large | 0.81 | 0.60-1.09 | 0.166 | 0.93 | 0.80-1.07 | 0.314 | 0.95 | 0.88-1.03 | 0.411 |
| Larger than average | 0.82 | 0.61-1.10 | 0.223 | 0.95 | 0.79-1.14 | 0.585 | 0.95 | 0.88-1.03 | 0.993 |
| Average | 0.83 | 0.62-1.12 | 0.223 | 0.96 | 0.73-1.27 | 0.795 | 0.93 | 0.86-1.00 | 0.951 |
| Smaller than average | 0.89 | 0.65-1.21 | 0.461 | 1.07 | 0.90-1.27 | 0.418 | 0.95 | 0.86-1.07 | 0.589 |
| Very small | 1 | - | - | 1 | - | - | 1 | - | - |
| **Weight at birth** | | | | | | | | | |
| Low | 0.96 | 0.92-1.00 | 0.042 | - | - | - | 0.99 | 0.97-1.02 | 0.750 |
| Normal | 1 | - | - | - | - | - | 1 | - | - |

*RR: Risk Ratio; CI: Confidence Interval; ARR: Adjusted risk ratio*

*\*Model adjusted with Propensity scores \*\*Model adjusted with confounding and/or covariates*